

CHAPTER 13

13. Water Meters

CHAPTER 13: WATER METERS

13.1 Introduction

A water meter is a scientific instrument for accurate measurement of quantity of water distributed to the consumer and efficient management of urban water supply. At present, about 20%–30% of these meters are non-functional due to poor selection, lack of maintenance and intermittent water supply.

Water meters play a very important role in transforming an intermittent system to a 24×7 water supply system. 100% metering is required for demand management and water conservation. Without 100% metering, 24×7 pressurised water supply system is not possible. Using water meters, real-time data on the volume of water being consumed by a consumer (residential or bulk) can be obtained, thereby encouraging the consumer to use water more efficiently. Flowmeters are the instruments installed for the measurements of the volume of water consumed or discharged from the source of water like a river, bore well or dam/reservoir to the water treatment plant (WTP) and subsequently, to the district metering areas (DMAs). Based on the requirement, some other features like pressure, temperature, turbidity, and water quality parameters can also be measured by the flowmeter.

Current problems with meters functioning in water supply systems include:

- i. Intermittent water supply can cause fluctuations in water pressure, affecting the meter's accuracy. This can lead to overbilling or underbilling and damage to the meter itself. Intermittent supply can also lead to air in water lines, which will also affect accuracy of the meter.
- ii. Water meters can become inaccurate over time due to wear and tear or damage, or the meter may not be properly sized, or air can get trapped in water meters. Foreign materials in the water supply (scale, rust, or sand from main breaks) can also damage metering components.
- iii. All meter types are susceptible to tampering, but mechanical meters are particularly susceptible. In India, most meters used today are mechanical, which means they can be easily tampered with. Customers can remove or damage parts of the meter to reduce their water bills or avoid paying altogether.
- iv. Some manufactured meters can be of poor quality, resulting in inaccurate readings or frequent breakdowns. This can lead to overbilling or under billing and additional costs for repairs or replacement. Hence, the domestic water meter sizes varying from 15 mm to 50 mm shall conform with IS 779 and ISO 4064. Also, bulk water meter sizes ranging from 50 mm and above shall conform with IS 2373 and ISO 4064.
- v. Meter installations can be susceptible to tampering and fraud. Some customers may attempt to tamper with their water meter or steal water by bypassing the meter.
- vi. Water meters can malfunction for various reasons such as mechanical failure or electrical issues with meter reading endpoints which may result in inaccurate readings or a complete meter failure.
- vii. Many water supply systems do not have adequate resources to maintain the meters. This can result in malfunctioning meters that do not provide accurate readings.

Water utilities can implement regular maintenance and repair programmes for water meters, take anti-tampering measures to prevent theft and misuse of water, and use modern and accurate metering technology. Additionally, efforts can be made to raise awareness among customers about the importance of paying for their water usage and the negative consequences of

tampering with meters.

The challenge of regular maintenance and ensuring good quality meters can be overcome by adopting policy of procuring and maintaining the meters by water utility and recovering the cost from households. With this arrangement the consumers will have a sense of responsibility on the meters and will try to maintain the meter and meter boxes. By this, it is possible to ensure that the water meters function throughout the project life. Metering policy as discussed in Section 13.2 shall be referred.

Management of water resources in a system is a function of the measurement of quantity of water at the source and its effective usage. These are indispensable for understanding the quantity of water being distributed in a system and its usage. Flowmeters are used to measure the quantity of water entering into the water supply systems from different sources such as water works, water treatment plants, or bulk water suppliers, and water meters are used to measure the quantity of water that is delivered to each metered consumer in the system.

Therefore, metering fulfils the need to know the water produced and distributed accurately with a clear understanding of water balance. A well-implemented metering system in the water distribution network shall also assist the technical staff in identifying the location where water loss/leakage is observed by comparing the water meter readings at the point of release of water with the readings at the consumer end. By estimating the level of water losses in a water supply system, unauthorised/illegal connections can also be identified.

The data obtained from a metering system also allows water managers to make a decision matrix for capital investments, maintenance, staffing, and various other aspects of the water supply systems. Therefore, water metering is an excellent application of the principle “to measure, is to know”. The knowledge of how much water is being used in the water distribution system is the key element in controlling the water loss and the revenue loss thereof.

Water tariffs based on the quantity of consumption can be used for increasing the income of water supply agency, cross-subsidising needy consumers, and managing water consumption. However, a tariff policy cannot be implemented without a well-established metering system. Therefore, it is very essential in water supply system for installing a metering system in the cities/Urban Local Bodies (ULBs).

Water meters and flowmeters consist of four basic components: (i) a sensor to detect the flow, (ii) a transducer to transmit the flow signal, (iii) a counter to keep track of the total volume of water passed, and (iv) an indicator to display the meter reading.

The following points indicate how a water meter is different from a flowmeter:

- It is a quantity meter and not a flow rate meter.
- Water meter is a mechanical, or electromagnetic, or ultrasonic device whereas flowmeter may be a mechanical or an electronic device.
- Water meter is always specified in two accuracies, i.e., lower range and upper range, whereas a flowmeter is specified in a single range accuracy.
- The upper range and lower range accuracies are 2% and 5% of the actual quantity, respectively, for the water meter, whereas it is variable for flowmeter, i.e., $\pm 0.5\%$ and $\pm 5\%$ as per the customer's requirement.
- Importance is not given for repeatability and linearity in the case of water meter. whereas importance is given in the case of a flowmeter because the accuracy of flowmeter performance is related to linearity and repeatability.

13.2 Metering Policy

Water metering means the method of measuring water consumption/use. In public water supply system water is supplied to the residential and commercial buildings, water meter measures the volume of water used. Water meters track water use. In addition to monitoring water consumption, a water meter saves the water. In an intermittent system people store water and when fresh water is received, they throw the earlier stored water. Because of this, vicious cycle of decreased number of hours of supply, increase in number of zones and subzones is observed in the practical operation of an intermittent water supply scheme. With metering it saves such water loss.

Benefits of using water meters: The main benefits are as follows:

- Incentive to conserve water
- Volumetric pricing
- Detect water wastage.
- Estimating subsidies
- Regular supply
- Lower energy consumption

Therefore, in managing water supply, it is to be noted that the demand management is not possible without 100% metering.

13.2.1 State/ULBs Metering Policy

The State/ULB must frame and implement a clear metering policy for achieving 100% metering for reduction of NRW. The Metering Policy should have the following basic principles embedded in it.

13.2.2 Legal Framework:

There should be a clause which provides “For calculating the amount payable by the owner for consumption of water supplied by the ULB/PHED/Board, the ULB/PHED/Board may determine the quantity consumed on the basis of reading recorded by a meter installed in the premises”.

13.2.3 Objectives of the Policy

The key objectives of the policy are:

- a) To promote water conservation by encouraging efficient water use
- b) To reduce Non-Revenue Water (NRW) and increase cost recovery.
- c) To ensure fairness and equity to all Consumers in charging for water services.
- d) To achieve 100% metering of all connections.
- e) To set out roles and responsibilities of both ULB/PHED/Board and Consumer in relation to the installation of metered connections, maintenance of the water meters.

13.2.4 Scope of the Policy

This policy should cover types of consumers for metering, selection of meter, its specification and installation guidelines. This also covers the tariff, billing & collection and grievance redressal

procedures related to metering. Further the responsibilities of the ULB/PHED/Board and consumers with regard to metering are described. Cost recovery and subsidy framework for the urban poor may be covered under the policy.

The ULB/PHED/Board shall install the water consumption meters for all the consumers having water connections in a phased and progressive manner commencing with high water consumption and high revenue categories and all non-residential and new Consumers.

13.2.5 Ownership of meters

As per IS 2065: 1983 reaffirmed in 2022, consumer meters shall be owned by ULB/PHED/Board and fixed rental charges will be levied on the consumers along with the water charges. The rental charges shall be used for the specific purpose of routine and periodical maintenance of the meters and regular meter replacement program by the ULB/PHED/Board. The day-to-day safety and upkeep of the meters shall be the responsibility of the Consumer. If any wilful tampering or damage of the meters occurs, other than natural wear and tear, the ULB/PHED/Board will undertake replacement of the defective meter and the cost of such exceptional meter repair or replacement of meter shall be recovered from the consumer with advance notice.

Points to be considered while framing metering policy:

- i. There is 100% consumer metering of all customers to realise a differential water tariff on volumetric basis and ensure that all the meters are functional throughout the design period of 30 years.
- ii. Each meter must be Geo tagged with GIS coordinates and shall be shown on GIS maps.
- iii. Customer meters may be mechanical Class B double jet meter or AMR meters or Smart meters (electromagnetic or ultrasonic).
- iv. For commercial, industrial and societies with high-rise buildings, automatic meter reading (AMR/ AMI) meters may be planned.
- v. The meter shall be compatible with the communication technology.
- vi. For procurement of meters through tender, ULB may empanel manufacturers of Mechanical, Ultrasonic and Electromagnetic meters conforming to latest IS or preferably ISO 4064_5: 2014, who possess certificates for performance, endurance and life cycle tests performed at Fluid Control Research Institute (FCRI) and Certified by FCRI. Only FCRI & OIML/ Measuring Institute Directorate (MID) tested and acceptable water meters shall be permitted / empanelled by ULB.
- vii. The Standards for mechanical meters shall be as per ISO 4064_5: 2014/IS 2373:1991/IS 779:1994; electromagnetic as per ISO 4064_5: 2014 and OIML R49 and for ultrasonic meters the standard shall be ISO 4064_5: 2014 and OIML R49.
- viii. Manufacturer must produce Life Cycle test certificate for at least one size of water meter each from domestic and bulk categories.
- ix. Indian standards should be brought at par with the International Organization for Standardization (ISO), till then meters should be as per ISO standard.
- x. Utility should have their own repair workshop of customer meters, or the empanelled manufacturers shall have service centre in the city or at place in consultation with ULB.
- xi. The consumers shall have all the options open to choose any type of water meter from empanelled makes and procure the same for installation on their connections.

- xii. Cost of providing all meters till its warranty period shall be a part of project cost and ownership of meters shall rest with ULB. ULB to ensure that all the non-functional meters are replaced suitably after the warranty period. Some states like Odisha procure water meters and recover the cost from the households over a period of time to ensure proper repair and replacement. This model may be followed in other states.
- xiii. ULB should engage meter provider/ manufacturer with O&M contract of meters for a period of 5 years so as to monitor the functioning of projects.
- xiv. During this period the responsibility of proper maintaining meters with repair of meter shall be with meter provider.
- xv. Mechanical meters should have warranty period of 5 years including repair & replacement of meters and if any repair work is required, the meter should be got repaired during the warranty period. The warranty period of Static meters may be considered as 10 years.
- xvi. After warranty period non-functional meters shall be systematically got replaced
- xvii. After warranty period if the non-functional meter is required to be replaced, consumers will be given 6-months' time for replacement, failing which they will be charged for 1.5 times more the consumption charged earlier and after 12 months the non-compliance will result in disconnection. Alternatively, the ULBs to procure and replace the meters and recover the cost in the water bills.
- xviii. Bulk meters are installed at suitable places like head works, inlet and outlet of the WTP, inlet pipes of each service reservoir, entry of DMA, etc. so that NRW reduction becomes possible.
- xix. All bulk meters are connected to the SCADA system or IoT systems.
- xx. The test certificates by manufacturers shall be accepted for all the diameters for new installation. Only in case of disputed readings, the meter will be tested at Municipal facility.
- xxi. The Ultrasonic / Electromagnetic Meters being accurate any variation in reading beyond $\pm 10\%$ of previously recorded consumption will be considered erroneous and subject to meter scrutiny and site investigation.
- xxii. Effective metering needs an efficient reading and billing mechanism. Meter reading is encouraged using various metering and communication technologies as discussed.
- xxiii. ULB will continue to play its role as a facilitator and regulator of water supply being an obligatory duty.
- xxiv. The Repair / Maintenance / Testing facilities shall be locally made available by the manufacturers at reasonable rates. This will be one of the criteria while empanelling the manufacturers.

13.3 Sizing of Water Meters

The nominal sizes of domestic water meter ranges from 15 mm to 50 mm as per {IS 779: 1994 (Reaffirmed 2015)} and bulk water meter ranges from 50 mm and above as per {IS 2373: 1981 (Reaffirmed 2017)}. Sizing of water meters is done considering the guidelines given in the Indian standard {IS 2401: 1973} and {ISO 4064 Part II: 2014}.

In general, the main considerations are as follows:

- i. Water meter should be selected according to the flow to be measured and not necessarily to suit a certain size of water main.
- ii. The maximum flow should not exceed the maximum flow rating.
- iii. The nominal flow should not be greater than the nominal flow rating.

- iv. The minimum flow measured should be within the minimum starting flow of the meter.
- v. Low head loss, long operating flow range, less bulky, and robust meter should be preferred.

13.4 Classification of Water Meters

Water meters are generally classified based on the different mechanisms used by the water meter to measure the flow of water passing through it. There are several types of flowmeter technology available in the market for bulk flow measurement and domestic water metering. The most prominent and widely used flowmeter for bulk flow measurement is the full bore, inline electromagnetic flowmeter. Traditionally, for household connections, mechanical Class B multijet meters were used. However, with advancements in technology, progressive water boards are opting for new smart technologies such as electromagnetic/ultrasonic static meters with automatic meter reading (AMR)/Advance metering infrastructure (AMI) solution, especially for high consumption customers. This is due to the various advantages they offer, such as the reduction of cycle time for billing and better customer service.

In India, currently, meters are broadly categorised into (i) Bulk flow and (ii) Domestic/Consumer revenue meters based on usage, as shown in Figure 13.1.



Figure 13.1: Type of meters in India based on consumer category

Water meters can also be classified based on metrological characteristics, as given in ISO 4064-3 Standard. The water meter classification is divided according to the water meter transitional flow rate (Q_2) and the minimum flow rate (Q_1), which indicates the sensitivity of the water meter, as shown in Table 13.2 below. Old regulations classify water meters into four classes: Class A, Class B, Class C, and Class D. Notably, Class D is the highest level as shown in Table 13.1.

Table 13.1: Water meter Classification- According to ISO 4064-3 (1999) Standard

Nominal Diameter	Q_n (m ³ /hr)	Q_{max} (m ³ /hr)	Class A			Class B			Class C			Class D		
			Q_{min} (litres/hr)	Q_t (litres/hr)	Ratio	Q_{min} (litres/hr)	Q_t (litres/hr)	Ratio	Q_{min} (litres/hr)	Q_t (litres/hr)	Ratio	Q_{min} (litres/hr)	Q_t (litres/hr)	Ratio
DN15	1	2	–	–		–	–		–	–		7.5	11.5	133

DN15	1.5	3	60	150	25	30	120	50	15	22.5	100	11.25	17.25	133
DN20	2.5	5	100	250	25	50	200	50	25	37.5	100	18.75	28.75	133
DN25	3.5	7	140	350	25	70	280	50	35	52.5	100	26.25	40.25	133
DN25	6	12	240	600	25	120	480	50	60	90	100	–	–	
DN32	6	12	240	600	25	120	480	50	60	90	100	–	–	
DN40	10	20	400	1000	25	200	800	50	100	150	100	–	–	

At present, Class A water meter has basically been withdrawn from the mainstream market, and Class B water meter is the most commonly used water meter in the market. Class C water meter has been more popular in the market because of its high measurement accuracy and ability to read at low flow. Class D water meter has higher requirements for manufacturing process and equipment and, at present, is mainly offered by as an ultrasonic water meter.

The water meter classification according to ISO 4064-3 Standard is shown in Table 13.2 below.

Table 13.2: Water meter Classification- According to ISO 4064-3 (2014) Standard

Size		Ratio	Q ₄ Overload flow	Q ₃ Nominal Flow	Q ₂ transitional flow	Q ₁ Min flow	Min reading	Max reading
DN (mm)	Inch		m ³ /hr		L/h		m ³	
15	1/2"	80	3.125	2.5	50.000	31.250	0.001	999999
		160			25.000	15.625		
		250			16.000	10.000		
		400			10.000	6.250		
		500			8.000	5.000		
		630			6.35	3.968		
20	3/4"	80	5.00	4.00	80.000	50.000	0.001	999999
		160			40.000	25.000		
		250			25.600	16.000		
		400			16.000	10.000		
		500			12.800	8.000		
		630			10.16	6.349		
25	1"	80	7.875	6.3	126.000	78.750	0.001	999999
		160			63.000	39.375		
		250			40.320	25.200		
		400			25.200	15.750		
		500			20.160	12.600		
		630			16.00	10.000		
32	1 1/4"	80	12.5	10	200.000	125.000	0.001	999999
		80			12.5	10		

Size		Ratio	Q ₄	Q ₃	Q ₂	Q ₁ Min	Min	Max
DN (mm)	Inch		Overload flow	Nominal Flow	transitional flow	flow	reading	reading
			m ³ /hr		L/h		m ³	
		160			100.000	62.500		
		250			64.000	40.000		
		400			40.000	25.000		
		500			32.000	20.000		
		630			25.40	15.873		
		800			20.000	12.500		
40	1 1/2"	80	20	16	320.000	200.000	0.001	999999
		160			160.000	100.000		
		250			102.400	64.000		
		400			64.000	40.000		
		500			51.200	32.000		
		630			40.63	25.397		
50	2"	80	25	20	400.000	250.000	0.001	999999
		160			200.000	125.000		
		250			128.000	80.000		
		400			80.000	50.000		
		500			64.000	40.000		
		630			50.79	31.746		
		800			40.000	25.000		

Q1 - lowest flow rate; Q2 - transitional flow rate; Q3 - permanent flow or nominal flow rate; Q4 - highest flow rate

13.5 Detailed Description of Meters and Applications

Mechanical meters have moving parts that detect the flow, such as a piston or impeller. They make up the vast majority of meters used in water distribution systems especially to measure the consumption and billing purpose at the domestic level. Electromagnetic and ultrasonic meters have no moving parts but detect the flow through the meter using electromagnetic waves and ultrasound waves, respectively. They are mostly for bulk metering, such as in very large pipes and/or where a high accuracy metering is required like DMA measurement.

Mechanical water meter like the single jet, multijet, piston type, and electromagnetic and ultrasonic meters are used for domestic purposes. The preferred diameter size for domestic metering is 15 mm to 40 mm. Bulk water meters are used to measure high water consumption for billing/water audit purposes by bulk consumers like commercial complexes, industries, etc. Generally, Woltman water meters (mechanical type), electromagnetic and ultrasonic water meter are used for bulk metering. The preferred diameter size for bulk metering is 50 mm to 150 mm.

As described in clause 8.5.8 of IS 17482: 2020 Standard, for water audit application, meters shall be preferred both at domestic metering and DMA. Sub-classification of different meters is shown in Figure 13.2 as under:

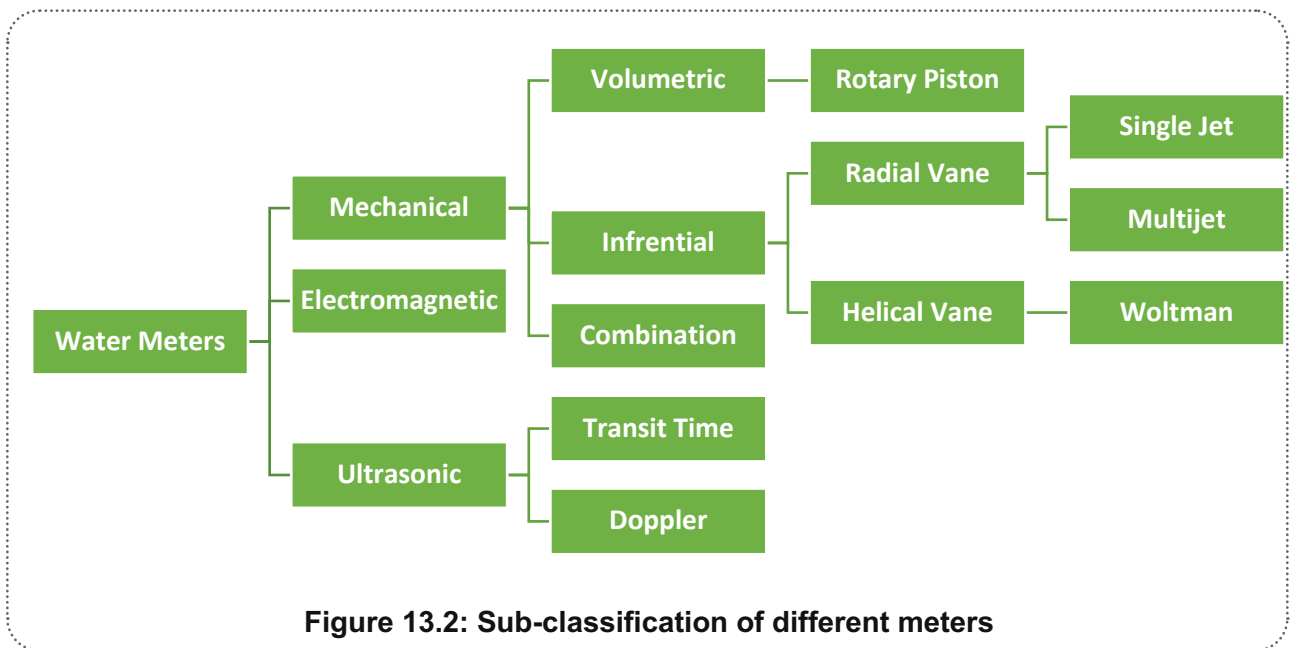


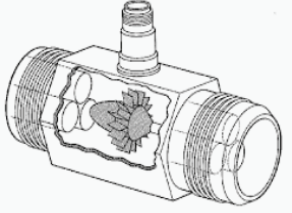


Figure 13.2: Sub-classification of different meters

Comparison of mechanical, electromagnetic and ultrasonic meters is given in Table 13.3 below.

Table 13.3: Comparison of Mechanical, Electromagnetic and Ultrasonic Meters

S. No	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
1.	Working principle	Paddle Wheel, Turbine or mechanical with moving counter	Electromagnetic induction principle Faraday's Law measurement	Ultrasonic Measurement principle Time of Flight measurement
2.	Build	(i) Moving parts are present (ii) Mechanically and magnetically coupled meter (iii) Dry/Wet Dial meter	(i) No moving parts (ii) Sensor in-build (iii) Dry Dial meter (iv) Can be inline type threaded/flanged end	(i) No moving parts (ii) Sensor in-build (iii) Dry Dial meter (iv) Can be inline type threaded/flanged end
3.	Available sizes	15 mm – 500 mm	15 mm – 3000 mm	15 mm – 4000 mm
4.	Application	Domestic meter: 15 mm to 40 mm Bulk meter (Woltman): 50 mm to 500 mm or more	Domestic meter: 15 mm to 40 mm Bulk meter: 50 mm to 3000 mm or more	Domestic meter: 15 mm to 40 mm Bulk meter: 50 mm to 4000 mm or more
5.	Standards	ISO 4064/IS 2373/IS 779	ISO 4064 and OIML R49	ISO 4064 and OIML R49
6.	Water quality	Suitable for potable water. Highly critical with suspended particles as it clogs the moving parts.	Suitable for potable water. No impact of particles.	Suitable for potable water. Highly critical with suspended impurity and turbidity as it deposits on the sensor face.
7.	Accuracy	Better than $\pm 2\%$ for upper flow range and $\pm 5\%$ for lower flow range.	Better than $\pm 2\%$ for upper flow range and $\pm 5\%$ for lower flow range.	Better than $\pm 2\%$ for upper flow range and $\pm 5\%$ for lower flow range.
8.	Installation orientation	Good performance under horizontal installation.	Good performance under horizontal, vertical, and inclined installation.	Good performance under horizontal, vertical, and inclined installation.
9.	Periodic maintenance	Very high as it has a lot of moving parts and wear and tear is a regular issue. There is no indication of wear and tear as no warning available other than the high-pressure drop.	Less and the expected life of the meter is a minimum of 10 years.	Less and the expected life of the meter is a minimum of 10 years.
10.	IP-68	Yes, with copper can	Yes	Yes

S. No	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
	availability	register version.		
11	Operating accuracy at low flow	Poor	Good	Good
12	Cost	Low initial cost but the high cost of maintenance due to moving parts and more frequent replacements like jamming of rotating wheels, counters, etc.	Cost increases with diameter.	Moderate.
13	Advantages	<ul style="list-style-type: none"> (i) Suitable for higher flows (ii) Can sustain hostile flow conditions (iii) External and internal regulator facilitates easy calibration (iv) Robust construction (v) Easy Maintenance 	<ul style="list-style-type: none"> (i) Suitable for wide range of flows (very low to high flows) (ii) Less sensitive to flow disturbances. (iii) Ready for Automatic Meter reading for water SCADA compliant (iv) Do not measure the air in the pipe (v) Can be installed in any Orientation. (vi) Life of meter 10 to 15 yrs. (vii) Low Maintenance required (viii) UOD0 – Meter works accurately with zero upstream and downstream length for installation 	<ul style="list-style-type: none"> (i) Suitable for wide range of flows (low to high flows) (ii) Less sensitive to flow disturbances. (iii) Ready for Automatic Meter reading for water SCADA compliant (iv) Do not measure the air in the pipe (v) Can be installed in any Orientation. (vi) Life of meter 10 to 15 yrs. (vii) Low Maintenance required. (viii) UOD0 – Meter works accurately with zero upstream and downstream length for installation

S. No	Attributes	Mechanical meters	Electromagnetic meters	Ultrasonic meters
14	Disadvantages	<ul style="list-style-type: none"> (i) Less sensitive to low flow (ii) Approach conditioning piping is required (iii) Limited to higher flows (iv) Bush leak problems (v) Meters measures air (vi) Brass body meter – prone to theft 	<ul style="list-style-type: none"> (i) Costlier than mechanical meters (ii) Water must be free from solid dirt particles 	<ul style="list-style-type: none"> (i) Costlier than mechanical meters (ii) Water must be free from solid dirt particles. (iii) Ultrasonic sensors may need to be cleaned periodically.
15	Representation			

13.6 Mechanical Meters

Mechanical meters are further classified in three categories, i.e., volumetric, inferential, and combination meters.

13.6.1 Volumetric Meters

Volumetric meters directly measure the volume of flow passing through them. Most volumetric meters use a rotating disk to measure the flow and are known as rotating piston meters. For application of volumetric meters, the total dissolved solids (TDS) level in water should be lower than 200 ppm.

Rotary Piston Meters

Rotary piston meters are positive displacement meters that use a rotating cylindrical piston to measure 'packets' of water moving from the inlet to the outlet of the meter.

Positive displacement meters are popular for their accuracy, long life, and moderate cost and are used for most domestic applications. Rotating piston meters are sensitive to sand and/or other suspended solids in the water that can get clogged between the piston and chamber wall, thereby clogging the meter. These meters are also sensitive to low flows and are particularly suitable for applications where the water flow rates are low or where frequent onsite leakage occurs. Rotary piston metre is shown in Figure 13.3.

The main disadvantages of rotating piston meters are:

- (i) being sensitive to suspended solids in the water;
- (ii) prone to relatively high-pressure losses; and



Figure 13.3: Rotary Piston Meters

(iii) bulky and expensive than other meter types.

13.6.2 Inferential Meters

Inferential meters do not measure the volume of water passing through them directly but infer the volumetric flow rate from the velocity of the water. Two categories of inferential meters commonly used are:

- (i) meters using a radial vane impeller; and
- (ii) meters using a helical vane impeller.

Radial vane impeller meters are further classified into a single jet and multijet (also known as multiple jets) meters. Helical vane

impeller meters are also called Woltman meters and use a propeller-like vane to increase the water velocity. Multijet meters are widely accepted in countries such as Brazil, Malaysia, Indonesia, India, Vietnam, etc., where the water supply system is intermittent.

13.6.2.1 Single Jet Meters

Single jet meters are inferential meters consisting of an impeller with radial vanes (also called a fan wheel) and use a single flow stream or jet to move the sensor. The rotational speed of the impeller is converted into a flow rate, which is registered on the meter. It is critical to precisely control the path of water through the single jet meter to obtain accurate readings. Thus, the inside portion of the single jet meter has to be manufactured to strict tolerances. Single jet water meter and its cross-sectional view are shown below in Figure 13.4.

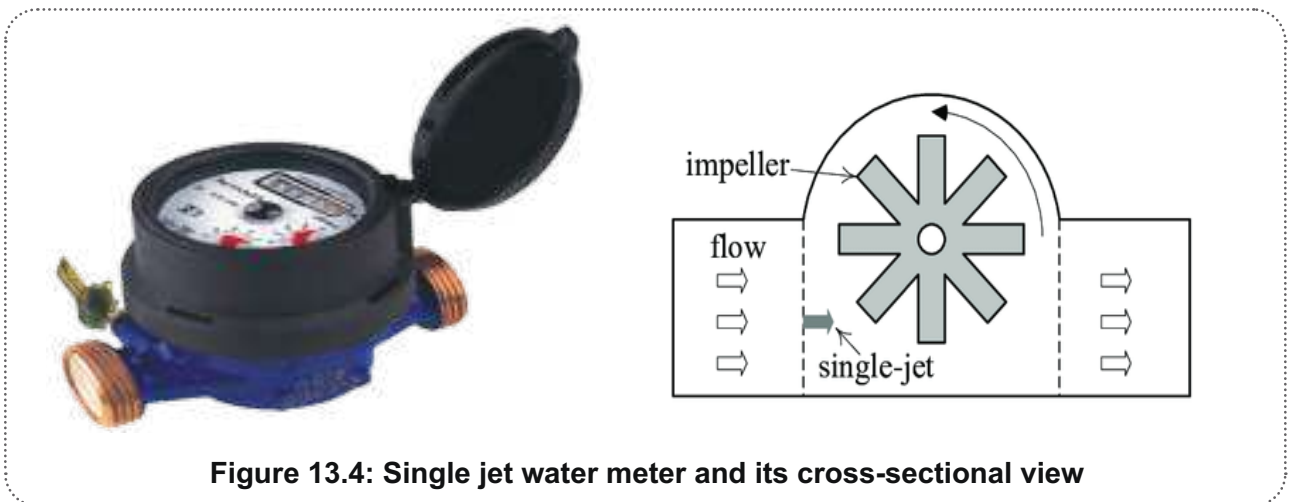


Figure 13.4: Single jet water meter and its cross-sectional view

The accuracy of single jet meters reduces due to wear in the moving parts with continuous usage over a period of time. In particular, the starting flow and accuracy of metering at low flow rates may deteriorate, and thus, older meters tend to under-register at low flow rates. At higher flow rates, the error can be positive or negative and may be exacerbated by sediments or deposits accumulating inside the meter. Air moving through the meter will also be registered as water, and thus, can lead to over-register of water flow. Traditionally, the metering chamber is made out of brass, but plastics are also becoming popular. The composite body (engineered plastics) for water meters makes it economical. Brass chambers make the single jet meter expensive,

especially in larger diameters. Single jet meters are thus mostly used in the size range of 15 mm to 40 mm.

Advantages of brass chambers for water meters:

- i. Steady water meter;
- ii. Protects the register can inside;
- iii. No health hazards;
- iv. Scrapped and re-use;
- v. End connection installation.

Disadvantages of brass chambers for water meters:

- A. Makes water meter heavier;
- B. Increases the cost of manufacturing by 5%–6%;
- C. Prone to theft due to the high value of scrap;
- D. Drift in accuracy over the period of time;
- E. Installation is restricted to horizontal position only.

13.6.2.2 MultiJet Meters

MultiJet meters are inferential water meters that use an impeller with radial vanes. The operation of MultiJet meters is similar to that of single jet meters, except that MultiJet meters use several jets to drive the impeller at multiple points. This implies that the forces applied on the impeller are better balanced than in single jet meters, thereby reducing wear on the moving parts and provides greater durability.

They are similar in construction to that of single jet meters, although MultiJet meters tend to be slightly larger in overall size. MultiJet meters are fitted with removable strainers on the inlet side of the meter, to facilitate cleaning of the same. A second internal strainer often covers the openings of the metering chamber. The internal strainer, if clogged, can affect the accuracy of the meter, thereby causing over-registration of the flow. MultiJet water meter and its cross-sectional view is shown in Figure 13.5.

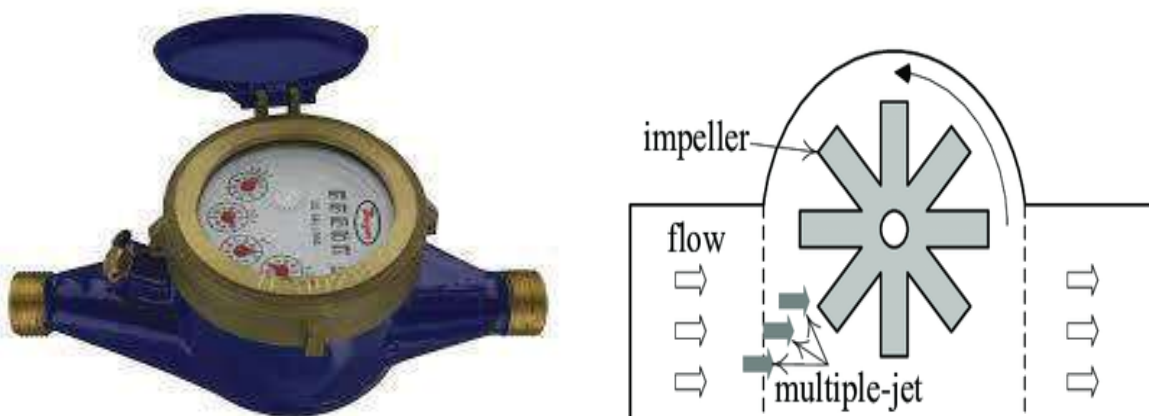


Figure 13.5: MultiJet water meter and its cross-sectional view

They normally use an internal bypass with a regulating screw to adjust the flow passing through

the impeller. This allows the manufacturer to adjust the meter's error curve to achieve the best accuracy before sealing the meter to prevent meter tampering. Traditionally, the meter body is made out of brass, but plastics are also becoming popular. The composite body (engineered plastics) for water meters makes it economical.

MultiJet meters use reliable and tested metering technology and normally have longer lifespan due to the balanced forces on the impeller. They are not sensitive to the velocity profile in the pipe and are tolerant of small, suspended solids in the water.

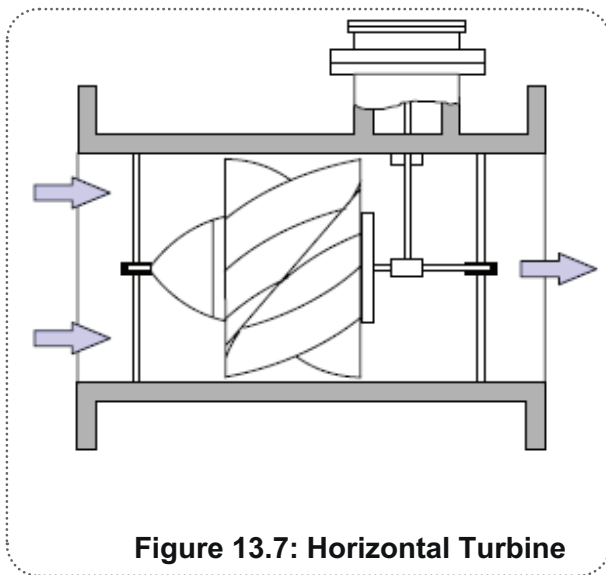
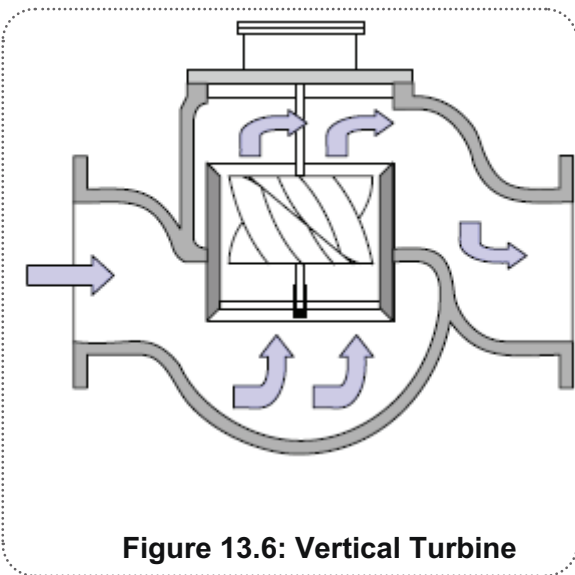
The disadvantages of MultiJet meters are:

- A. Sensitivity to the installation position, thereby affecting accuracy;
- B. Often bulkier than single jet meters;
- C. Not being sensitive to low flow rates;
- D. Starting flow rate can deteriorate significantly with time;
- E. Accuracy may be significantly affected by clogs in jet openings, if any;
- F. A brass body prone to theft, due to the high value of scrap;
- G. Meter life of three to four years.

13.6.2.3 Woltman Meter

The Woltman meter is an inferential meter that uses an impeller with helical vanes, which resembles a fan or boat's propeller. As water flows over the helical vanes, it causes the impeller to rotate, and the rotation is then transmitted to the dial via reduction gearing.

There are two different types of Woltman meters, horizontal turbine, and vertical turbine. Horizontal Woltman meters have their inlets and outlets directly in line with the pipeline, and the axle of the helical vane is parallel to the flow. Water flows directly through the meter with minimal disturbances by the meter body. Horizontal Woltman meters are used in a large range of pipe sizes, typically having a diameter between 40 mm and 600 mm. Vertical Woltman water meter is designed for industrial and irrigation applications in sizes 50 mm and 200 mm for the cold meter. Both vertical turbine and horizontal turbine are shown in the Figure 13.6 and Figure 13.7, respectively.



Woltman meters are affected by flow distortions or changes in meter dimensions that may interfere with the way water passes through the meter. Deposits in the meter can cause over-registration at medium flows and under-registration at low flows.

All Woltman meters have dry, sealed dials. The easy passage of water through horizontal



Figure 13.8: Woltman Meter

Woltman meters reduces pressure loss through the meter. However, since the transducer needs to turn the circular movement of the impeller through 90 degrees to connect it to the counter, greater torque is required, which reduces the meter's sensitivity to low flows. Another limitation of Woltman meters is that they are sensitive to disturbances in the flow passing through them. Bends or valves close to a horizontal Woltman meter can affect the meter's accuracy. Spiralling flow, caused by two successive bends in different planes, is particularly unfavourable for their accuracy. Woltman meter is shown in Figure 13.8.



Figure 13.9: Combination Meter

13.6.3 Combination Meters

They do not use a specific mechanism to measure the flow but are made up of two meters of different diameters that are combined to measure a wide range of flow.

They are generally used to measure high flow rates with extremely widespread flow profiles and also to measure very small flow rates for leakage detection and are ideal for fire service pipes. Combination Meter is shown in Figure 13.9.

13.7 Electromagnetic Water Meters

Electromagnetic water meters function on the principle of electromagnetism, called Faraday's Induction Law, to measure the velocity of the water passing through it. In an electromagnetic meter, a magnetic field is created across the pipe. When water, which is an electrical conductor, moves through the magnetic field, a voltage is induced, which is detected by electrodes in the body of the meter. The voltage is directly proportional to the flow velocity, which is then used to calculate the volume. Domestic electromagnetic meter DN15 to DN40 is shown in Figure 13.10 and bulk electromagnetic meter DN50 to DN300 is shown in Figure 13.11.



Figure 13.10: Domestic Electromagnetic meter DN15 to DN40



Figure 13.11: Bulk Electromagnetic meter DN50 to DN300

The voltage is measured by two electrodes placed at right angles to the magnetic field. The sensor measurement is transmitted via an electric signal to an electronic counter, which converts the velocity readings to volume. The volume of consumption and/or flow rate is normally displayed on an LCD screen.

Electromagnetic water meters are accurate within their measuring range. Electromagnetic water meter's accuracy is defined as $\pm 5\%$ for lower operating flow range and $\pm 2\%$ for upper operating flow range (as per ISO 4064 Standard).

Advantages of electromagnetic meters are as follows:

- i. No obstruction to flow;
- ii. No pressure loss;
- iii. No moving parts subject to wear, therefore there is hardly any maintenance;
- iv. Highly accurate and immune to variations in fluid density, pressure, viscosity, or temperature;
- v. Measures only water, no air;
- vi. No drift in accuracy over the product life;
- vii. Composite body, not prone to theft;
- viii. Very good low flow; and
- ix. Meter life more than 10 years according to R800 metrology.

Electromagnetic domestic meters operate on battery and battery life is minimum of 10 years.

13.8 Ultrasonic Water Meters

Ultrasonic water meters utilise the properties and behaviour of sound waves passing through moving water. ultrasonic water meters are designed on the transit time principle.

A transit time ultrasonic meter has two sound transducers mounted at opposite sides of the pipe at an angle to the flow. Each of these sound transducers will, in turn, transmit an ultrasound signal to the other transducer. The differences in the transit times of the signals determine the velocity and the volume is derived from the velocity. The measuring principle is called 'bidirectional ultrasound technique based on the transit time method', which is a proven, long-term stable and accurate measuring principle.

A domestic ultrasonic meter DN15 to DN40 is shown in Figure 13.12 and bulk ultrasonic meter

DN50 to DN300 is shown in Figure 13.13.



**Figure 13.12: Domestic Ultrasonic Meter
DN15 to DN40**



**Figure 13.13: Bulk Ultrasonic Meter DN50
to DN300**

The accuracy of transit time ultrasonic meters depends on the ability of the meter to accurately measure the time taken by the ultrasound signal to travel between the sound transducers. Larger pipes have longer path lengths and thus, the speed of the signal, and the flow rate can be measured with higher accuracy. Transit time meters work better in clean fluids and thus, are ideal for drinking water pipes. They measure the average velocity of fluid but are sensitive to the velocity profile in a pipe. In some cases, multi-beam devices are used to improve meter accuracy.

The ultrasonic water meter's accuracy is defined as $\pm 5\%$ for lower operating flow range and $\pm 2\%$ for upper operating flow range as per ISO 4064_5:2014 Standard.

Deposits on the inside pipe surface can affect signal strength and performance. The disadvantage of the ultrasonic water meters is that air in the liquid, turbulence, deposits on the sensors, and water hammer (pressure transients) affects its performance. Additionally, the ultrasonic water meters operate on battery and battery life is a minimum of 10 years.

13.9 Installation and Testing of Water Meters

13.9.1 Installation of Water Meters

In order to ensure proper working of meters, BIS has given guidelines in IS-2401:1973 and ISO 4064_5:2014 Part 5 for their installation, as per the drawing given in it. At the same time, following guidelines should be kept in mind while installing the meters.

- i. The water meter being a delicate instrument shall be handled with great care. Rough handling including jerks or fall are likely to damage it and affects its accuracy.
- ii. The meter shall be installed at a spot where it is readily accessible. To avoid damages and overrun of the meter due to an intermittent water supply system, it is always advisable to install the meter so that its top is below the level of the communication pipes. This ensures that meter always contains water when there is no supply in the line. Also, the minimum straight length of pipe before and after the meter, as per the drawing, shall be observed. This assures laminar flow of water to the meter.
- iii. The meter shall preferably be housed in a chamber with a protective lid. It should never be buried underground, installed in the open, or under a water tap so that water may not directly fall on the meter. It should be installed inside inspection pits built out of bricks or

- concrete and covered with the lid. It should not be suspended.
- iv. The meter shall be installed so that the longitudinal axis is horizontal, and the flow of water should be in the direction shown by the arrow cast on the body.
 - v. Before connecting the meter to the water pipe, it should be thoroughly cleaned by installing, in the place of the water meter, a pipe of suitable length and diameter and letting the passage of a fair amount of water flow through the pipework to avoid the formation of air pockets. It is advisable that the level of the pipeline where the meter is proposed to be installed should be checked by a spirit level.
 - vi. Before fitting the meter to the pipeline, check the unions nuts in the tail pieces and then insert the washers. Thereafter, screw the tail pieces on the pipes and install the meter in-between the nuts by screwing. To avoid its rotation during operation, the meter should be kept fixed with suitable non-metallic clamps. Care should be taken that the washer does not obstruct the inlet and outlet flow of water.
 - vii. The protective lid should normally be kept closed and should be opened only for reading the dial.
 - viii. The meter shall not run with free discharge to the atmosphere. Some resistance should be given in the downside of the meter if static pressure on the main exceeds 10 m head.
 - ix. A meter shall be located where it is not liable to get the severe shock of water hammer which might break the system of the meter.
 - x. Given to the fine clearance in the working parts of the meters, they are not suitable for measuring water containing sand or similar foreign matter. In such cases, a filter or dirt box of the adequate effective area shall be fitted on the upstream side of the meter. It should be noted that the normal strainer fitted inside a meter is not a filter and does not prevent the entry of small particles, such as sand.
 - xi. Where intermittent supply is likely to be encountered, install an appropriate air valve before the meter to reduce inaccuracies and to protect the meter from being damaged. At higher altitude, if the meter is installed as above, the problem will be eliminated.
 - xii. Every user expects a problem-free installation of the meter and, thereafter, only accurate readings. Regular monitoring is desirable in order to avoid failures.
 - xiii. The meter is installed in the pipeline using flanged or threaded connections giving due consideration for conditioning sections. It should be seen that stress-free installation is carried out in the pipeline.
 - xiv. Installation in 'U' shape is essential in an intermittent water supply to avoid direct air pressure on the impeller during the starting of supply hours, which may damage impeller.

13.9.2 Testing and Calibration of Water Meters

The testing and calibration of a water meter is essential before putting it into use as it is a statutory requirement. It is also essential to test it periodically in order to ascertain its performance during the life of the meter as its accuracy of measurement may deteriorate beyond acceptable limits over a period of time. Calibration consists of comparing the meter reading with the reading obtained from a standard of higher accuracy than the test meter and with established uncertainty. Meters may also be tested using volumetric testing using calibrated tanks. Calibration is usually done in a laboratory at a variety of flow rates, as well as varied densities and temperatures. The calibration factors of the meter are determined during calibration.

The accuracy of a water meter is divided into two zones, i.e., (i) lower measurable limit in which $\pm 5\%$ accuracy from minimum flow Q_1 to transitional flow Q_2 (exclusive), and (ii) upper

measurable limit in which $\pm 2\%$ accuracy from transitional flow Q2 (inclusive) to maximum flow Q4 (as per ISO 4064_5:2014 Standard).

The metering accuracy testing is carried out as per {IS 779: 1994/ {ISO 4064_5:2014} $Q_{min}/Q1$, $Q_t/Q2$, and $Q_n/Q3$ separately.

Where

- Q₁: Minimum flow rate at which the meter is required to give indication within the maximum permissible error tolerance. It is as mentioned in IS 779:1994 and is determined in terms of numerical value of meter designation in case of ISO 4064_5:2014. Q₁ value is derived from the ratio, i.e., $Q_1 = Q_3/\text{ratio}$.
- Q₂: The transitional flow rate at which the maximum permissible error of the water meter changes in value. Q₂ is 1.6 times of Q₁.
- Q₃: Permanent flow rate as mentioned in ISO 4064-2014 for each size of the meter.
- Q₄: The overload flow rate at which the meter is required to operate in a satisfactory manner for short periods of time without deterioration. Q₄ is 1.25 times of Q₃.

Dynamic Ratio – Q_3/Q_1

13.9.2.1 Procedure for Conducting the Test

Water meter is fixed on a test bench horizontally or vertically, or in any other position for which it is designed and with the direction of flow as indicated by the arrow on its body. By adjusting the position of the regulating valve on the upstream side, the rate of flow is adjusted. At the desired rate of flow, the difference in pressure gauge readings fitted on the upstream and downstream side of the water meter is noted. The flow is now stopped with a regulating valve and the measuring chamber is emptied and zero water levels on the manometer attached to the measuring chamber are correctly adjusted. The initial reading of the water meter from its recording dial is noted. Now the flow at the set rate is passed through the water meter and the discharge is collected in the measuring chamber. After passing the desired quantity of water through the meter, the flow is once again stopped. The discharge, as recorded by the measuring chamber, is noted. The final reading of the water meter is noted. The difference between the initial and final readings of water meter provides the discharge figure recorded by the water meter. Now the discharge recorded by measuring tank is treated as ideal. The discharge recorded by water meter is compared with this ideal discharge. If the quantity recorded by water meter is more than the ideal, the meter is called running fast or vice versa. The difference in the quantity recorded by the meter from the ideal quantity is considered as an error. This error is expressed in percentage.

If the limits of error for the meter exceed as specified in the IS concerned, the meter is readjusted by the regulator if it is available in the meter. A change in position of the regulating screw will displace the error curve (calibration curve) in parallel to the former position. With the closing of the regulating orifice, the curve will shift upward while opening the same will lower the curve. If the curve does not get into an acceptable limit, the meter is not used. Some of the organisations are accepting accuracy limit for repaired water meter that is double the value of new water meters at respective zones, i.e., for upper zone accuracy is $\pm 4\%$ and for lower zone accuracy is $\pm 10\%$.

The meter testing is normally carried in the meter testing laboratory with the help of one of the

following methods.

1. Gravimetric
2. Volumetric
3. Prover
4. Master or reference meter
5. Tow tank – current meter calibration

13.9.2.2 Point Calibration Test

All the meters manufactured shall be tested/calibrated for accuracy at Q1, Q2, and Q3 flow rates and shall meet the acceptance criteria of errors less than the MPE, as per ISO 4064 standard.

Calibration consists of comparing the meter reading with the reading obtained from a standard of higher accuracy than the test meter and with established uncertainty. The standard may be a reference master meter or a complete test bench which are traceable back to more fundamental measures of mass, time, and volume. Test report format is as under:

Meter Serial Number	3 Point Accuracy Test			Date of testing
	Q1 (%)	Q2 (%)	Q3 (%)	

13.9.2.3 Lot Acceptance Test: Meter Testing from first lot of meters

Sample meters shall be sent to approved laboratory from the first lot of meters based on the sampling plan given at Table 13.4 for conducting the below tests.

- i. Accuracy test at Q1, Q2, $0.35(Q2 + Q3)$, $0.7(Q2 + Q3)$, Q3 and Q4 as per ISO 4064 standard
- ii. Pressure loss test
- iii. Static pressure test
- iv. AMR communication test with the meter
- v. IP68 test on two sample meters
- vi. Life cycle test on three sample meters

Table 13.4: IS 779 Sampling plan for Sample Size and Criteria for Acceptance

Size of the lot	Size of First Sample	Acceptance Number	Rejection Number	Size of Second Sample	Size of Cumulative Sample	Cumulative Acceptance Number
Up to 50	5	0	1	-	-	-
51–150	13	0	2	13	26	1
151–280	20	0	3	20	40	3
281–500	32	1	3	32	64	4
501–1200	50	2	5	50	100	6
1201–3200	80	3	6	80	160	9
3201–10000	125	5	9	125	250	12
10001–35000	200	7	11	200	400	18
35001 and over	315	11	16	315	630	26

13.9.2.4 Certificates to be provided with the meters during QAP Approval

All the below certificates shall be submitted during QAP approval process.

- i. OIML R 49/ MID (Module B+D or Module H1) Certificate
- ii. MAP and the endurance certificate from approved laboratory for each size
- iii. IP-68 Certificate from FCRI for the model of meters
- iv. Certificate of Approval of Model as per Legal Metrology Act
- v. ISO 17025:2005 certificate

13.9.2.5 Setting up a Test facility

The utility should set up a test facility in their premises to test accuracy, pressure loss, and static pressure of water meters to attend customer grievance.

13.10 Repairs, Maintenance and Troubleshooting of Water Meters

13.10.1 Introduction

Water meters are mechanical devices which normally deteriorate in performance over time. The fact that a meter does not show outward signs of any damage and has a register that appears to be turning does not mean that the meter is performing in a satisfactory way. It is necessary to ascertain preventive care for water meter after proper installation.

The ultrasonic and electromagnetic water meter's accuracy performance is assured for the life of the product. Turbine meter should be checked periodically for bearing wear since presence of air or particles in the water may damage the moving parts over time.

13.10.2 Preventive Maintenance

- i. Proper handling, storage, and transportation of water meters
- ii. Cleaning the dirt box or strainer wherever installed
- iii. Replacing the gaskets, if any
- iv. Cleaning the chamber in which the meter is installed and keep free from flooding and seepage
- v. Removing the meter for further internal repair/replacement if it does not show the correct reading pattern

13.10.2.1 Breakdown Maintenance

The only basic breakdowns observed during the periodical inspection are replacement of broken glass, lid, and fallen wiper, wherever provided. If a meter found not working, then it shall be removed immediately and sent to the meter service workshop. In meter workshops, the repair process typically involves several key steps:

- i. Disassemble water meters including strainer, measuring unit, regulator, registering the device, etc.
- ii. Clean all disassembled spare parts in detergent solution in warm water.
- iii. Inspect the cleaned parts and replace worn parts and gaskets if any.

- iv. Inspect the meter body spur threads and cover threads.
- v. Inspect the sealing surface on the meter body and paint the meter body, if necessary.
- vi. Inspect the vane wheel shaft pinion, bearing and pivot.
- vii. Inspect the vane wheel chamber.
- viii. Reassemble the water meter properly after reconditioning.
- ix. Calibrate and test the repaired water meter for leakage and accuracy as per IS 6784: 1996 (Reaffirmed 2017).
- x. Make an entry in the life register of that water meter for keeping history records.

The Table 13.5 gives remedies to common issues in a meter.

Table 13.5: Troubleshooting of water meter

S. No.	Trouble	Cause	Remedy
1.	Meter reads in reverse direction	Might have been installed in the reverse direction.	Check the arrow on the meter body and install the meter properly, if necessary.
2.	Meter not recording	Impeller to register link broken.	Remove the meter for servicing and repairs.
3.	Continuously moving pointer/digit rotates but no change in the indicator	Pointer and drum link missing. Drum defect.	Remove the meter for servicing and repairs. Remove the meter for servicing and repairs.
4.	Dial/glass foggy	Climatic condition.	Wait for climate change if it is the rainy season
5.	Meter suspected to be slow or fast	Inlet flow disturbance, missing internally defective, deteriorated magnets in case of magnetic meter.	Clean the external filter/dirt box, where provided, and the inbuilt strainer. Ensure full open condition of the upstream valve. If doubt persists, remove meter for testing, servicing and repair.
6.	Bush/gland leakage	Gland deformity.	Remove meter for testing and servicing.
7.	Regulator, head, body leakage	Regular washer damaged, loose screw.	Remove the meter and repair.
8.	Physical damage to meter including broken seal	Improper installation.	Remove meter for testing, servicing, and repair, physical protection arrangement be made.
9.	No water available past the water meter even though the inlet side is charged	Semi positive/positive displacement meter with jammed piston.	Meter is acting as a stop valve. Remove it for inspection, servicing, and repair.

In the case of smaller-sized water meters, it is advisable to check cost-benefit ratio before getting them repaired.

13.10.2.2 Prevention of Tampering of Water Meters

In order to prevent tampering, the following precautions should be taken:

- i. The water meters shall be properly installed in the chamber or in C.I. covers equipped with locks and keys to avoid tampering.
- ii. The water meters must be sealed properly.
- iii. The water meter shall not allow reversible flow; it should register flow in forward direction only.
- iv. The water meter dials should be easily readable without confusions.
- v. The lids and glass of water meters must be made up of tough materials as per IS 779: 1994 and shall be replaced when necessary.
- vi. Wiper or dial, as far as possible, is avoided.
- vii. In the case of magnetically coupled meters, the proper material to shield magnets must be provided to avoid the tampering of such meter by outside magnets in the vicinity of the meter.
- viii. Periodic inspection/checking at the site is essential to ensure the proper working of the meter.
- ix. Special sealing arrangements may be necessary and provided for bulk meters whereby unauthorised removal of the meter from the connection can be detected.

Despite the above, to tackle the problems of tampering, suitable penalty provisions/clauses shall be there in the rules or the water supply agreement with the consumer. This will also discourage consumer tendency to neglect water meter safety.

13.10.3 Trend of Replacement of Water Meters

At present, there is no specific Indian certification process of validating the accuracy of water meters or flowmeter. In general, if a water meter goes out of order due to any physical damage or non-operation of the registration device and is beyond economical repair, it should be replaced with immediate effect. In the Indian context, the performance of water meter or flowmeter depends upon:

- i. The quality of water meter produced by the manufacturer, which differs from manufacturer to manufacturer;
- ii. The design of pipeline and fittings in line with the meter;
- iii. The workmanship and care when handling and installing the meter;
- iv. The pattern of water passing through the meter;
- v. The type of supply of water, whether it is continuous or intermittent;
- vi. The meter maintenance, testing;
- vii. The proper selection of meter; and
- viii. Installation procedure as per {ISO 4064:2014 Part 5} to be followed.

The performance of a water meter is required to be watched continuously with suitable history sheets. Any abnormality noticed needs immediate action. Timely removal of a faulty meter, especially mechanical ones, prevents cascading and cumulative damages.

Looking at the number of transactions involved, bulk meters shall be given priority in replacements. Based on the experience gained for a specification work, a well-planned programme for periodical meter testing, servicing, repairs, and replacement, wherever necessary, shall be designed.

13.11 Meter Reading Systems

13.11.1 Manual Meter Reading System:

Many of the mechanical meters do not have remote reading capability. The meter readers have to visit the consumer premises one by one, walk to the meter, and note down the registered readings manually. These readings are recorded manually in books or on cards and later fed manually to a customer accounting or billing system. In some cases, meter readers use handheld data entry terminals to record meter readings. Data from these devices are transferred electronically to a billing system. In other cases, the key entry has been replaced by mark-sense card readers or optical scanners.

The environment of meter reading is usually is not favourable to the meter reader as most of the water meters are installed in an underground chamber; these chambers are filled, in many cases, with water, reptiles, or insects. Access to these meters is often obstructed when they are installed on consumers' premises. Sometimes, manual work is involved in opening the chamber covers. Some consumers connect their electrical earth terminal to the water utility pipe which endangers the safety of the meter reader. If during a meter reading visit, the consumer premises are not accessible, the meter reader will have to visit it again, which increases the cost of meter reading. Alternatively, an "estimated" reading is used for billing, which can result in customer dissatisfaction due to high or low estimates.

13.11.2 Automatic Meter Reading (AMR) System

In AMR system, a meter reader carries a handheld device with a built-in or attached radio transceiver to collect meter readings from an AMR-capable water meter, generally called "smart meters". In this case, the meter readings are automatically collected without manual intervention. This metering data is then transferred to a central computer either through cellular network or through USB cable for analysis and billing purpose. Readings from AMR can be obtained by a simple walk-by or drive-by method, where the meter reader either walks or drives down the street while automatically downloading the meter data. Figure 13.14 represents an automatic meter reading (AMR).

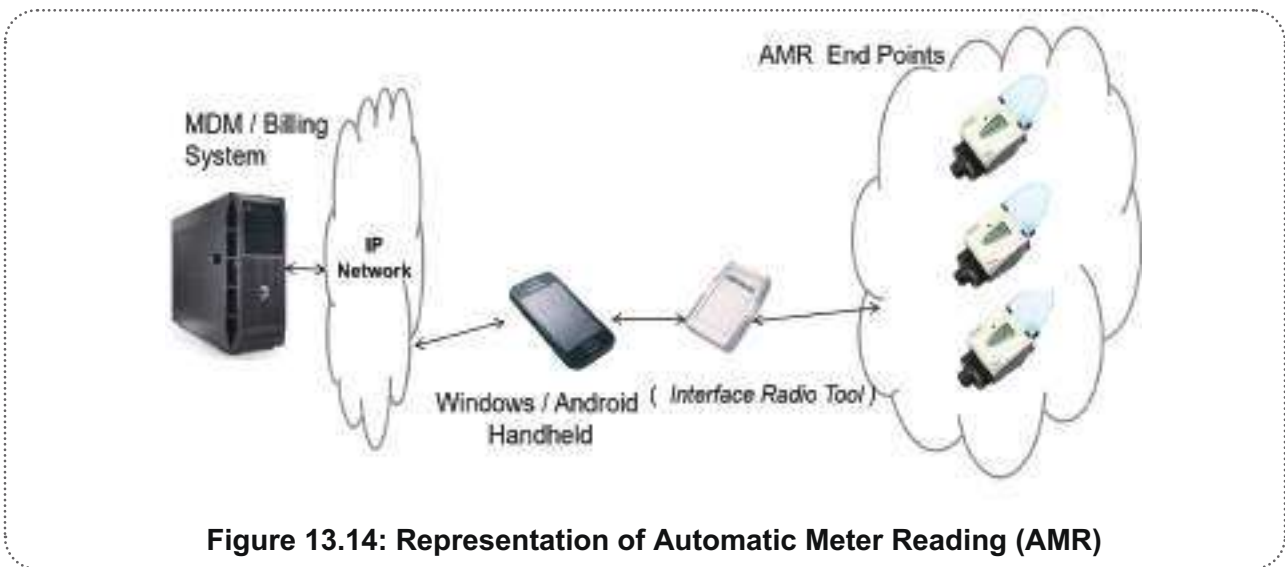


Figure 13.14: Representation of Automatic Meter Reading (AMR)

In AMR system, the meter readers read the meters either on monthly or bi-monthly basis as per the utility billing schedule. AMR system is much safer for meter readers since readers are not

required to enter consumer properties, which in turn reduces the likelihood of injury. Due to the infrequent schedule of collecting data, any problems in the meter may go unnoticed for a significant period of time.

Benefits ascribed to the installation of an AMR system:

- i. Increased revenue from previously unaccounted water;
- ii. Accurate meter reading, no human error, and efficient billing;
- iii. Reduced meter reading costs including both regular cycle reading and special reads;
- iv. Improved safety of meter readers;
- v. Increased customer service;
- vi. Identifying and locating losses (customer and system);
- vii. Theft detection;
- viii. Improved cash flow;
- ix. Conservation/Efficiency improvements;
- x. Readings from data log containing register reads as frequently as every 15 minutes;
- xi. Drastic reduction of estimated readings.

13.11.3 Advanced Metering Interface (AMI)

Many utilities have used the AMR system as a stepping-stone between standard metering and AMI systems. Some utilities made changes as technology became available, while other utilities made system decisions for financial reasons, and a few other utilities wanted to try out the technology as pilot before committing to an AMI system. However, if the goal is to eventually have a full AMI system, then it is smart to explore the cost-effectiveness of growing from AMR to AMI.



Figure 13.15: Advanced Metering Interface (AMI)

AMI comprises of smart meters and adds two-way communication between the meter and utility, and between the meter and consumer. This implies that in addition to providing readings, the meter can also receive (and often act on) instructions sent from the utility or consumer. Figure 13.15 and Figure 13.16 shows advanced metering interface (AMI).

AMI is more complex than AMR and requires a large physical communication network. AMI

performs the function of data collection similar to an AMR system; however, instead of holding the collected data until a meter reader can collect it, AMI relays the data to the owner of the meter in real-time. Because AMI can relay data in real-time and has a physical network, it has additional features.

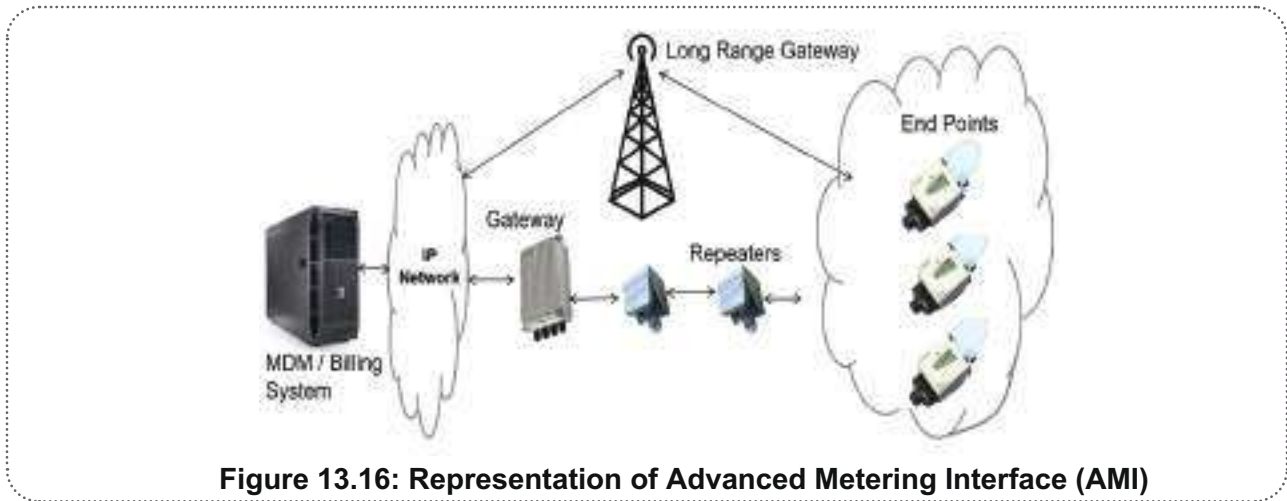


Figure 13.16: Representation of Advanced Metering Interface (AMI)

An AMI system can perform the functions of an AMR system as well as:

- i. Daily, hourly, or 15-minute read increments without reading staff;
- ii. Improved customer service;
- iii. Customer web portals;
- iv. Quick and accurate replies to inquiries;
- v. Faster resolution of billing disputes;
- vi. Select billing date;
- vii. Real-time diagnostic operation and maintenance reports;
- viii. Targeted data collection and report generation;
- ix. Operational updates for the collector, repeaters, and endpoints;
- x. Faster leak detection in water network with analytical module.

Data is transmitted in AMI systems in the following ways: one-way, two-way, and quasi two-way. The most appropriate option will largely depend on how much data is collected and the requirement of the utility.

13.11.4 Methods of AMI Data Transmission

13.11.4.1 Radio Technologies:

Because of its reliability and cost-effectiveness, radio frequency (RF) is the most common communication technology for AMI/AMR systems. Antennas or transmitters are attached to the meter or register, and data is transmitted from the meters and the data collectors by RF.

13.11.4.2 Non-Radio Technologies:

Non-radio technologies for data transmission include power lines, cable, cellular, satellite, telephone, GSM/GPRS, LoRaWAN, LAN, NB-IOT, IIOT, optical fibre cable, etc.

13.11.4.3 Meter Data Management:

Meter Data Management (MDM) is a common platform where any smart meter can directly communicate and report meter reading data, alarms, tamper alerts, etc. to the user. The MDM

is a cloud-based application capable of communicating with smart meters via different communication protocols. In the case of non-communicating meters, users can use android applications to collect data and send it via a mobile network to MDM for analysis, visualisation, and accuracy checks.

13.12 Model Compliance Sheet for Meter Tenders – AMR/AMI

The Model Compliance for AMR/AMI Meters is given as per the below Table 13.6

Table 13.6: Model Compliance Sheet for Meter Tenders – AMR/AMI

Sr. No.	Particulars	Compliance (YES/NO)	Documentary proof Page no.
1	Meter Measurement technology (Mechanical or Electromagnetic or Ultrasonic), IP68, facility for report communication interface	YES/NO	
2	Meter approvals and certification <ul style="list-style-type: none"> • OIML R 49 and or ISO 4064 • MID Module B + D for International /imported meters • Legal metrology Manufacturing plant – Quality Certificate <ul style="list-style-type: none"> • ISO 9001 	YES/NO YES/NO YES/NO YES/NO	
3	Performance and Endurance Certificate from FCRI is submitted for each size of meter	YES/NO	
4	Operating range ratio – Q3/Q1 -R 160 minimum for mechanical and R 400 minimum for smart meters	YES/NO	
5	Meter Warranty from Manufacturer – 5 Years for AMR with mechanical meters or 10 years for Static Meters.	YES/NO	
6	Meter inbuilt battery (more than 5 years for mechanical meters and with more than 10 year battery life for static meters)	YES/NO	
7	Is Manufacturer Authorisation Form (MAF) from meter manufacturer submitted along with the bid	YES/NO	
8	Meter Manufacturer India Presence <ul style="list-style-type: none"> • India Local entity • Foreign entity • Local Service Support from OEM 	<ul style="list-style-type: none"> • YES/NO • YES/NO • YES/NO 	
9	Meter and Communication System (AMI) solution from same meter	YES/NO	

Part A- Engineering

Sr. No.	Particulars	Compliance (YES/NO)	Documentary proof Page no.
	manufacturer or AMI system fixed network/LPWAN/NB-IoT		
10	AMI system of meter manufacture/ reading device/meter reading software/ gateways/ concentrator/ repeaters/ radio frequency / protocols/ battery life/ LPWAN/IoT is under warranty for 10 years O&M	YES/NO	
11	Is the Billing system offered capable of integration with AMR/AMI meters, water billing, supports collection, regularisation, grievance handling, Consumer information and integrate with meter and data management, GIS, Payment Gateway, MIS reports, customer portal, that will allow the Concessionaire/contractor to tailor the product to the specific working environment of the Municipality	YES/NO	
12	Is Smart Water Meter mechanical/electromagnetic/ultrasonic with certifications as required with facility for remote communication interface, battery-operated and warranty for 5 years for mechanical and 10 years for Electromagnetic/ Ultrasonic water meter proposed by the concessionaire / contractor. The mechanical/electromagnetic/ultrasonic water meter should maintain its accuracy +/-% over its lifetime and the measuring units should be m ³ for volume and m ³ /h or l/h for flow rate	YES/NO	
13	Is the smart Water Meter mechanical/electromagnetic/ultrasonic Manufacturer proposed by the concessionaire/contractor has supplied in India or abroad at least 50,000 Static AMR/AMI Meters in one (1) lot of any sizes in last seven years	YES/NO	
14	Is the Smart Water Meter mechanical/electromagnetic/ultrasonic Manufacturer proposed by the concessionaire have manufacturing	YES/NO	

Sr. No.	Particulars	Compliance (YES/NO)	Documentary proof Page no.
	capacity to supply 1 lac meters in two years or as per needs of ULB.		
18	Is the concessionaire/contractor in agreement to the condition precedent scope in six months of GIS based consumer survey, commercial data validation, asset study, network study for gateways installation, ward wise consumer regularisation and new application execution and come out with projection of total water that can be supplied to potential water volume that can be sold	YES/NO	
19.	Is the concessionaire/contractor in agreement to set up a customer relationships management centre with test bench and participate with Municipality in the citizen engagement programme	YES/NO	
20.	Is the Concessionaire/contractor in agreement to the performance-based KPIs during the O&M period of 5 years for mechanical and 10 years for Electromagnetic/ Ultrasonic water meter	YES/NO	
21	For Mechanical/ electromagnetic/ ultrasonic meters weather proof mountable cabinet is provided for the electronics that should not cause obstruction to the RF/GSM/GPRS signal	YES/NO	
22	Meter proposed by concessionaire/contractor should provide three-point calibration with calibration certificate available for each unit. Agreeable for inspection by Municipality/ ULB before despatch	YES/NO	
23	Meter proposed by the concessionaire/contractor should be tamper proof and should have advanced diagnostics with indicators/alarm on display for tampering, reverse flow, and leakage	YES/NO	
24	All the supplied smart water meters, their peripherals and equipment's must	YES/NO	

Sr. No.	Particulars	Compliance (YES/NO)	Documentary proof Page no.
	have a written warranty from the manufacturers covering not less than 5 years for mechanical and 10 years for Electromagnetic/ Ultrasonic water meter from date of commissioning		

The characteristics of different types of meters with communication technologies are given in below Table 13.7.

Table 13.7: The characteristics of different types of meters with communication technologies

Characte ristics	Non AMR- Mechani cal Meters	AMR Meters- Mechani cal	Advanced AMR- Mechanic al	Ultrasonic AMR Water Meters	Electromagnetic Water Meters – AMR	NB-IOT Ultrasonic Water meters
Cost	X	3X	6.5X	10X	10X	10X
Product Lifetime	Upto 5 years	upto 5 years	7-8 Years	10-12 Years	10 -15 years	10-15 Years
Battery Life (Based on One Communi cation per Month)	NA	4-5 Years	7-8 Years	10-12 Years	10-12 Years	10-12 Years
Battery Life (Based on One Communi cation per Day)	NA	4-5 Years	10 Years	10-12 Years	12-15 Years	12-15 Years
Battery Life (Based on One Communi cation per hour)	NA	3 Years	5 Years	10-12 Years	12-15 Years	12-15 Years
Consump tion Index Storage Frequenc y	NA	Daily and hourly Index available while fetching data through AMR	Daily and Hourly Index available	Daily Index and Hourly Index available	Daily and Hourly Index available	Daily and Hourly Index available
Consump tion index recording capability	NA	Daily and hourly Index available	Daily and hourly Index available	Daily and Hourly Index available	Daily and Hourly Index available	Daily and hourly Index available

Part A- Engineering

Interoperability (Capability to convert AMR to AMI and vice versa)	NA	Not possible	Yes	Yes	Yes	Yes
Accuracy (R=Q3/Q1) As per MID certification (Accuracy for all meter type will change in Intermittent Water Supply)	Upto R50	Upto R80	Upto R160	Upto R800	Upto R800	Upto R800
Minimum flow rate	30 liters/hour	30 liters/hour	15 liters/hour	3 liters/hour	3 liters/hour	3 liters/hour
Nominal Flow rate	1600 liters/hour	2500 liters/hour	2500 liters/hour	2500 liters/hour	2500 liters/hour	2500 liters/hour
AMR Dataset capability to do online high resolution water balance and leak estimation	NA	Hourly Water Balance Possible , Leak estimation not possible	Hourly Water Balance Possible and Leak Estimation Possible without affecting battery life	Hourly Water Balance Possible and Leak Estimation Possible without affecting battery life	Hourly Water Balance Possible and Leak Estimation Possible without affecting battery life	Hourly Water Balance Possible and Leak Estimation Possible without affecting battery life

13.13 Flowmeters

A flowmeter is the device used for the measurement of liquids in closed conduits. This device differs on the type of liquid conductive or non-conductive, and also has the other related aspects of the principle of operation. In water supply, mechanical, electromagnetic, or ultrasonic types of flowmeters are used. However, those are segregated depending on various points, i.e., working principle, conductivity of liquid and its quality, the basic and overall accuracy of the flowmeter, calibration possibility, reading are taken from field or online, etc. The supply and delivery manufacturer should have ISO quality standard (IS 9001:2015) certification and flowmeter testing conforming to ISO 17025: 2005 (Reaffirmed 2017). There are installation standards that need to be adopted for different flowmeters. Figure 13.17 shows electromagnetic flowmeter, Figure 13.18 shows an ultrasonic insertion flowmeter, and Figure 13.19 shows an ultrasonic clamp-on flowmeter.

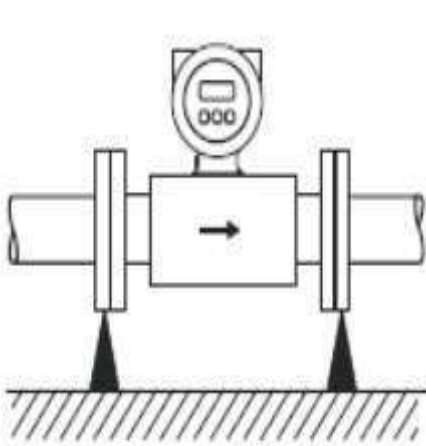


Figure 13.17: Electromagnetic flowmeter

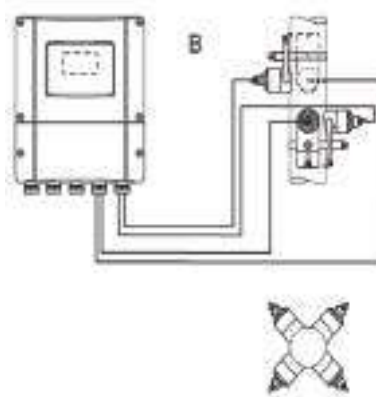


Figure 13.18: Ultrasonic Insertion flowmeter

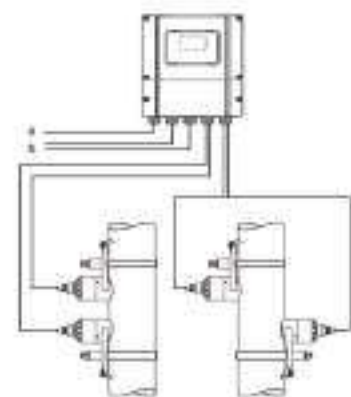


Figure 13.19: Ultrasonic Clamp-on flowmeter

13.13.1 Methods for Metering Flow

Various methods are available for the metering flow rate and total flow. Each method has its own specific characteristics, which are directed towards individual installation requirements. In the water industry, a flow rate meter is termed as the flowmeter and the total flowmeter is termed as the water meter. A wide range of standard terms is used to describe the essential performance characteristics of instruments and sensors. Some of these terms are as follows.

13.13.1.1 Accuracy

It is defined as the difference between the reading of an instrument and the true value of the measured variable expressed as a percentage of either full scale or true value of the measured variable, either in terms of full scale or flow rate of the flowmeter. As much as possible, the accuracy should be selected in terms of percentage of flow rate as it remains constant within the rangeability irrespective of variation in flow rate.

13.13.1.2 Range

The difference between the maximum and minimum values of the physical output over which an

instrument is designed to operate normally.

13.13.1.3 Rangeability/Turndown Ratio

Describes the relationship between the range and the minimum quantity that can be measured.

13.13.1.4 Linearity

The degree to which the calibration curve of a device matches a straight line.

13.13.1.5 Resolution

The error associated with the ability to resolve the output signal to the smallest measurable unit.

13.13.1.6 Repeatability

The quantity which characterises the ability of a measuring instrument to give identical indications or responses for repeated applications of the same value of the quantity measured under stated conditions of use.

13.13.2 Types of Flowmeters

In water works, normally, the following types of flowmeters are used. These are classified with their advantages and disadvantages as described in the Table 13.8.

Table 13.8: Types of Flowmeters

S. No.	Types of Flowmeter	Advantages	Disadvantages
A	Differential Pressure/Head Flowmeter		
1.	Orifice Flowmeter	i. It can be used for all fluids except for some exceptions ii. No moving parts iii. Flow rate, indication, integration is easily obtained iv. It can be fitted in any configuration of the pipeline v. Suitable for any pipe diameter vi. The signal can be transmitted to long distance vii. Good accuracy viii. Suitable for extreme temperature and pressure ix. Calculation possibilities for unusual situations	i. Rangeability 4:1 ii. Energy cost in terms of head loss iii. Ideal conditions are required for good accuracy iv. Suitable for a particular range of Reynolds number v. Accuracy in terms of span vi. Minimum slope for tapping piping has to be maintained, i.e., 1:10 vii. Very long conditioning section required viii. Intensive maintenance required ix. Edge sharpness of the orifice must be assured x. It requires isolation of pipeline during installation

S. No.	Types of Flowmeter	Advantages	Disadvantages
2.	Venturi Meter	Advantages are similar to orifice flowmeter, and less pressure loss and hence less energy cost.	Advantages are similar to orifice flowmeter mentioned at Sr. No. i, iii, iv, v, vi, and x in addition to the high capital cost
3.	Pitot Tube	i. As mentioned under orifice flowmeter except at Sr. No. vii. ii. It does not require isolation of pipeline for installation and comparatively capital cost of the flowmeter is less. iii. Head loss is also less.	As mentioned under orifice flowmeter at Sr. No. i, iii, v, vi, vii with addition of inferiority in accuracy as it being point velocity measurement
4.	Annubar (Average Pitot Tube)	Similar as mentioned under pitot tube in addition to higher accuracy	Similar as mentioned under pitot tube except for inferiority in accuracy, i.e., accuracy improves due to averaging of multi-ported pressures.
B Linear Flowmeter			
1(a)	Turbine Wheel Flowmeter (Full Bore or Inline)	i. Excellent accuracy, linearity, and repeatability ii. Usable at extreme temperature and pressure	i. Suitable for only for low viscosity ii. Moving parts and hence, wear iii. Sensitive to contamination iv. Flow profile sensitive and needs conditioning section v. Affected by overloading, the danger of overspeeding vi. Sensitive to vibration vii. Isolation of pipeline is required for installation.
1(b)	Turbine Wheel Flowmeter (Insertion Type)	i. Isolation of pipeline is not required ii. Low cost	i. Inferior accuracy because of point velocity measurement ii. Suspended impurities can clog it iii. In addition to the above, the disadvantages mentioned under the turbine wheel flowmeter (full bore) are also applicable

S. No.	Types of Flowmeter	Advantages	Disadvantages
2 Variable Area Flowmeter (Rotameter)			
	Variable Area Flowmeter (Rotameter)	<ul style="list-style-type: none"> i. Inexpensive ii. No power supply required for local indication iii. No conditioning section iv. Easy maintenance 	<ul style="list-style-type: none"> i. It requires vertical installation ii. Affected by the density and temperature of the fluid iii. Affected by vibration and pulsation
3 Vortex Flowmeter			
3(a)	Full Bore or Inline Type	<ul style="list-style-type: none"> i. No moving part ii. Robust construction iii. Unaffected by temperature, pressure, and density changes 	<ul style="list-style-type: none"> i. Conditioning of long approached section ii. Span limitation due to viscosity iii. Shedding rate is nonlinear between 2000 and 10000 Reynolds's number iv. Available up to 400 mm size due to constraints of sensitivity v. Isolation of pipeline is required for installation
3(b)	Insertion Vortex Flowmeter	<ul style="list-style-type: none"> i. Isolation of pipeline for installation is not required ii. Less costly than that of full bore iii. In addition to the above, the advantages mentioned under full bore vortex flowmeter are also applicable. 	<ul style="list-style-type: none"> i. Inferior accuracy due to point velocity measurement ii. In addition to the above, the disadvantages mentioned under full bore vortex meter are applicable except at Sr. No. V.
4 Magnetic Flowmeter			
4(a)	Full Bore (Inline) Flowmeter	<ul style="list-style-type: none"> i. Unobstructed flow passage ii. No moving parts iii. No additional pressure drop iv. Unaffected by changes in temperature, density, viscosity, electrical conductivity v. Flow range setting can be optimised vi. Suitable for water containing suspended solids vii. Short conditioning section is required as it is insensitive to flow profile 	<ul style="list-style-type: none"> i. Air or gas inclusion causes the error ii. Minimum required conductivity of fluid 0.5 ms/cm. iii. Isolation of pipeline is required for installation iv. Vacuum creation may detach inner liner

S. No.	Types of Flowmeter	Advantages	Disadvantages
		<ul style="list-style-type: none"> viii. Measures flow both the directions ix. Unaffected by contamination and deposit x. Minimum maintenance xi. Good linearity xii. The smaller diameter flowmeter can be used on a bigger diameter pipe with the help of reducers having angle not more than 16 degrees 	
4(b)	Insertion Magnetic Flowmeter	<ul style="list-style-type: none"> i. Less costly than that of full bore ii. No isolation of pipeline for installation iii. Advantages mentioned under Sr. Nos. ii, iv, v, vi, viii, ix, x, xi of full bore (inline) magnetic flowmeter is applicable 	<ul style="list-style-type: none"> i. Inferior accuracy due to point velocity measurement ii. Long conditioning section is required iii. Sensitive to vibration iv. Periodic cleaning of the electrode is required v.
5	Ultrasonic Flowmeter		
5(a)	Doppler Type Ultrasonic Flowmeter	<ul style="list-style-type: none"> i. Unobstructed flow passage ii. No moving parts iii. No pressure drop iv. Measures flow in both directions v. Installations of individual elements in existing pipe lines possible vi. Minimum maintenance vii. Economical for large diameter pipe viii. Suitable for turbid water 	<ul style="list-style-type: none"> i. Not suitable for clear water ii. Accuracy is inferior iii. It requires a long conditioning section
5(b)	Transit Time (Time of Flight) Ultrasonic Flowmeter	<ul style="list-style-type: none"> i. Advantages mentioned under Sr. nos. i, ii, iii, iv, v, vi, vii of Doppler type are applicable ii. Accuracy is improved in multipath iii. Accuracy is superior in insertion (wetted type) than that of clamp type. 	<ul style="list-style-type: none"> i. It requires long conditioning section ii. Not suitable for turbid water or carrying air/gas bubbles.

13.13.2.1 Ultrasonic Flowmeters

Ultrasonic flowmeters utilise the properties and behaviour of sound waves passing through moving water. The ultrasonic flowmeters are of two types depending on different working mechanisms, viz., transit time meters and Doppler meters.

13.13.2.2 Transit Time Ultrasonic Flowmeters

Transit time ultrasonic flowmeters are based on the phenomenon that sound waves slow down

when moving through water against the flow, and speed up when they move with the flow. A transit time ultrasonic flowmeter has two sound transducers mounted at opposite sides of the pipe at an angle to the flow. Each of these sound transducers will in turn transmit an ultrasound signal to the other transducer. The differences in the transit times of the signals determine the flow velocity and flow rate.

The accuracy of the transit time ultrasonic flowmeters depends on the ability of the meter to accurately measure the time taken by the ultrasound signal to travel between sound transducers. Larger pipes have longer path lengths, and thus, the speed of the signal and the flow rate can be measured with higher accuracy. Transit time meters work better in clean fluids and thus are ideal for drinking water pipes. They measure the average velocity of fluid but are sensitive to the velocity profile in a pipe. In some cases, multi-beam devices are used to improve meter accuracy.

Permanently installed transit time meters are often called wet transducer meters since their sound transducers are in direct contact with the fluid. These meters are very reliable. Ultrasonic flowmeters typically have relative errors between 0.25% and 1%. They can be used on pipes ranging from 10 mm to greater than 2 m in diameter, although they are not often used on small diameter water pipes. The ideal flow velocity range for good accuracy is 0.5 to 10 m/s.

The inline type meter, with IP 68 protection class, is constructed as a vacuum chamber of moulded composite material or suitable metal body. Thus, the electronics are fully protected against penetration of water. Water consumption is measured electronically, as a volume, using the ultrasound signal. Through two ultrasonic transducers, an audio signal is sent with and against the flow direction. The ultrasonic signal travelling with the flow will be the first to reach the opposite transducer, while the signal running against the flow will be received a little later. The time difference between the two signals can be converted into flow velocity. The measuring principle is called 'bidirectional ultrasound technique based on the transit time method', which is a proven, long-term, stable, and accurate measuring principle.

Clamp-on transit time meters use sound transducers that are clamped externally onto the walls of a pipe to provide portable non-intrusive flow measurement. Practically, they can be used on any pipe material including metals, plastics, fibre, cement and lined or coated pipes. A disadvantage of ultrasonic flowmeter is that the ultrasonic pulses must traverse pipe walls and coatings, and therefore the thicknesses and acoustic properties of these elements must be known. Deposits on the inside pipe surface can affect signal strength and performance. Additionally, air in the liquid, turbulence, deposits on the sensors, and water hammer (pressure transients) affects its performance.

Modern clamp-on meters incorporate microprocessors that allow mounting positions and calibration factors to be calculated for each application and can provide accuracies of 0.5% to 2%. The advantages of transit time flowmeters include high accuracy and reliability, which makes them cost-effective for use in large pipes. The clamp-on version of the meter is easy to install without the need to shut down the pipe. However, transit time flowmeters are sensitive to distortions in the velocity profile of a pipe, require an electricity supply, and are not suitable for dirty waters.

13.13.2.3 Doppler Ultrasonic Flowmeters

Doppler ultrasonic water meters function based on the Doppler Effect, which is the measure of

the change in the frequency of a sound wave when it is reflected back from a moving object. Doppler ultrasonic flowmeters create a soundwave in a moving fluid which, upon contact with dirt particles or air bubbles, reflect back towards the origin of the signal. The reflected ultrasound waves are detected by a receiver, and the change in the wave frequency is measured. This shift can then be related to the velocity and thus flow rate of the water. Doppler ultrasonic flowmeter is shown in Figure 13.20.

They can only be used for water that contains particles or air bubbles, and thus they are more suitable for dirty water applications such as raw water. A drawback of Doppler meter is that fluid particles in the water sometimes move slower than the water itself, or are concentrated in parts of the pipe with lower velocities (e.g., close to the sides or bottom of the pipe), which can result in a measurement error of 10% or more. They are also sensitive to disturbances in the velocity profile and require an electrical supply. While they are not suitable as billing meters, they can be cost-effective as flow monitors if measurement accuracy is not critical.



Figure 13.20: Doppler Ultrasonic Flowmeter

13.13.2.4 Sensor Based Flowmeter

Remote flowmeter, for use on gravity fed and pressurised piped water systems, is designed to monitor functionality and performances of water supply networks. The pipe flowmeter utilises the ultrasonic flowmeter, microprocessor, and a body trace chip to monitor water usage on piped systems. The sensor has a plastic enclosure waterproof, anti-explosion, heat and cold resistant, and utilises food-compliant plastic.

After installation on the water pipe, when the water tap is opened, the flow of water passing through the sensor results in the rotation of the internal turbine. The energy of the fluid passing through it moves a rotor that have magnets on his blades; the volume of the water is registered by monitoring the speed of the rotation of the magnets passing by a metal point. This information is then transformed in digital data by the microprocessor, and the data sent by the sim card embedded in the sensor. The sensor transmits hourly flow data that can be uploaded on cloud platforms. Dashboards have to be designed according to the user needs. This is an advance technology and may be applied in water supply systems.

Meters shall also have an actual flow rate and totalised value for effective water management purposes. The accuracy shall be $\pm 0.5\%$ of reading for flowmeters.

The supplier shall have full ISO 9000 series accreditation and fully traceable calibration methods. The suppliers shall also have a testing facility in India so that methodology and procedures can be verified. Each flowmeter shall be wet calibrated with a two-point calibration to verify performance in accordance with the specification and submit the report for the same. The testing facility shall be duly accredited in accordance with ISO/IEC 17025:2005 (Reaffirmed 2017) Standards. Bidders must upload/attach the certificate of ISO/IEC 17025 from flowmeter manufacturer as a mandatory requirement of this enquiry/tender which is duly accredited according to ISO/IEC 17025:2005 (Reaffirmed 2017) facilities in India.

The sensors for flowmeters shall be as per DVGW/ISO standard lengths (ISO 13359:1998) so that interchangeability can be carried out for the applicable flowmeter sizes. The sensor shall

also have built-in grounding and empty pipe detection electrodes of SS 316 for detecting partial flow conditions and efficient operation purposes. The liner material shall be polyurethane (PU) or hard rubber suitable for media/application/service. The appropriate certificate for drinking water approval shall be a part of it and the same shall be uploaded or attached while bidding as a mandatory requirement of this tender. The sensor and transmitter shall be capable of working in a tropical environment. The flowmeter body shall be available in flanged or with custom connectors as specified in the datasheets.

The sensors shall be rated IP 68. The transmitter shall be rated IP 67 in line with local operating conditions. Installations shall be made with cables and/or conduits that guarantee the integrity of the system under all operational conditions. The transmitter/converter shall be the wall-mounted type with a two-line display for the indication of an actual flow rate and totalised value. A glass window within the protection enclosure with optical switches shall be provided for local reading purposes. The non-corrosive, polycarbonate housing material of the enclosure shall be sufficient to guarantee five years of operational life. Magnetic flowmeters should be supplied with built-in software features to analyse and continuously monitor the health of the sensor, display errors in text format. The transmitter should be capable of performing the verification programme on demand or on request without taking the meter off the line or without any additional external hardware/accessories.

The transmitter shall be capable of being fully programmable. It shall have a set-up menu so that all relevant parameters may be user-set from the self-prompting driven menu. The transmitter shall have three totaliser units, one scalable pulse output, and one current, i.e., 4–20 mA HART output. The current output shall be galvanically isolated. It shall be fitted with a switched-mode power supply capability of 0–250V or 24 DC and 45–65Hz to cope with power transients without damage. The totaliser value shall be protected by EEPROM during a power outage and utilises an overflow counter.

The transmitter shall be having the facility of indicating electrical conductivity measurement. It shall be possible to separate the sensor and transmitters up to 300 meters without the need for signal boosters or amplifiers. The pulsed DC type flow sensors shall normally be installed remotely from the transmitters and are to be subject to harsh environmental conditions. At some locations, underground chambers shall be used and, in such cases, the operation under fully submerged conditions may occur. Thus, in either case, a full IP68 design is necessary. The sensor shall, therefore, be made from SS 304 materials with flanges of up to PN10 rating from carbon steel as per EN 1092-1, suitably treated for the application. The sensor coil housing shall be powder-coated cast aluminium with NEMA 4X rating (IP 68) or painted steel. The paint shall be of durable anti-corrosion grade. The tube liner shall be suitable for media/application/service.

The manufacturer shall have a full system of local offices in India and full-service capability in the metro cities throughout the country. Full contact details for key personnel, both national and local shall be furnished on request. The supplier shall provide evidence of at least five years of involvement in the manufacturing of meters worldwide. The water flowmeter manufacturer/supplier shall provide full data on each meter required, including optimising and sizing programmes calculation sheet. The proposed flowmeter model number by the manufacturer shall be available on their official website with a complete technical catalogue or operating manual for flowmeter (sensor /transmitter). The official latest meter sizing programme shall be available on the official website of the flowmeter supplier. The proposed model code shall be available and acceptable globally.

13.13.3 Installation and Maintenance of Flowmeters

Every user expects a problem-free meter installation of the meter and thereafter only accurate reading. Regular monitoring is desirable in order to avoid failures.

It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of an ultrasonic flowmeter, the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline.

The meter is installed in the pipeline using flanged or threaded connections giving due consideration to conditioning sections. It should be seen that a stress-free installation is carried out in the pipeline. It is essential to install the flowmeter co-axially to the pipeline without protruding any packing or gasket into the water flow stream. In the case of an ultrasonic meter, the probes are welded on the pipeline which requires care to see that no projection is protruding in the pipeline. In this case, onsite calibration is essential. Whenever converters are used with primary elements, it should be observed that the connection between them should be protected against lightning strikes and any other interference signal.

The installation on the existing water supply requires shutting down the water supply. This necessitates the shortest installation time possible. The installations are strictly carried out as per manufacturers' recommendations.

In the case of differential pressure type flowmeter, the impulse piping requires special care in respect of slope and protection. Similarly, long disturbance free straight sections should be provided for uniformity. Installation should be vibration free as moving parts in the flowmeter, wherever present, will get worn out in addition to the effect on overall accuracy of the flowmeter. Installation in 'U' shape is essential for intermittent water supply.

Flowmeters should be provided with battery backup in order to retain integrator reading during failure of electric supply.

13.13.3.1 Repairs, Maintenance, and Troubleshooting of Flowmeters

Modern development in the flowmeter measurement is that in most of the equipment a self-monitoring facility is provided with which the maintenance staff monitors the health of the equipment. A number of instruments are enunciating the error conditions.

As far as orifice, Pitot tube, Venturi, and Annubar flowmeters are concerned, they require regular purging of impulse piping. Similarly, the transducers require periodical checking of zero and range setting. For the orifice, it is essential to check sharpness of the edge as in the case of its deterioration or damage the flowmeter reading may vary up to 20%.

Ultrasonic flowmeters and magnetic flowmeters are self-monitoring and provide information regarding deviation in accuracy or failure of probe or electrode. Whenever cleaning of probes or electrodes is required, those should be cleaned as per manufacturers' recommendation.

Turbine meter should be periodically checked for bearing wear since presence of air in the liquid may damage the bearing because of over speeding.

Where deposits are to be expected in any flowmeter, the same should be regularly inspected and cleaned as per the experience gained over time, as these deposits affect the accuracy of the measurement, vortex meter, magnetic flowmeter, and ultrasonic flowmeter may show erroneous reading in the presence of deposits. Average accuracies of various

flowmeters are given in Table 13.9. In an intermittent water supply, the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation and subsequent descaling affect flowmeter working especially differential pressure type and turbine meters.

Table 13.9: Average Accuracies of Various Flowmeters

Sr. No.	Type of flowmeter	Accuracy %
1.	Square edge orifice	±1S
2.	Venturi	±1S
3.	Pitot	±2S
4.	Annubar	±1S
5.	Turbine	±0.5R
6.	Rotameter	±2S
7.	Vortex	±1R
8.	Magnetic	±0.5R
9.	Doppler	±2S
10.	Transit time	±1R

Legends: S: in terms of full scale; R: in terms of flow rate.

Table 13.10 gives broad areas of Application of Flowmeter for Liquid

Table 13.10: Broad Areas of Application of Flowmeter for Liquid

Sr. No.	Type of flowmeter	A	B	C	D
1.	Orifice	0	(+)	0	0
2.	Venturi	0		0	0
3.	Variable Area	0	0		
4.	Annubar	0		0	0
5.	Turbine	0		0	(*)
6.	Insertion turbine	0		0	0
7.	Vortex	0			
8.	Insertion Vortex	0		0	0
9.	Electro Magnetic	0	0	0	0
10.	Insertion Electro Magnetic	0		0	0
11.	Doppler	0		(+)	(+)
12.	Transit time	0	(+)	0	0

Legends: 0: Suitable, generally applicable; C: Large liquid flows (>1.7 × 10⁴ L /min.); (+) is worth considering, sometimes applicable; (*) is worth considering, limited availability or tends to be expensive; D: Large water pipes (> 500 mm dia); A blank indicates unsuitable; liquids (temp.>200°C) not applicable; A: General liquid application (< 50 CP); B: Low liquid flows (<2 L /min)

A flowmeter suspected to be malfunctioning is also tested for its accuracy of the measurement. The testing is done as per {IS 6784: 1996 (Reaffirmed 2017)}/ {ISO 4064-2014 Part III}. A faulty flowmeter, if found to be repairable, is repaired, tested and calibrated for its accuracy before installation. To establish a meter factor, the indicated volume of fluid that passes through a meter is compared to the true volume measured in a container of known size, or a master meter. Temperature and pressure correction are then applied.

The flowmeter manufacturer/supplier shall provide full data on each meter required, including optimising and sizing programmes calculation sheet. The proposed flowmeter model number by the manufacturer shall be available on their official website with a complete technical catalogue/operating manual for flowmeter (sensor/transmitter). The official latest meter sizing programme shall be available on the official website of the flowmeter supplier. The proposed model code shall be available and acceptable globally.

The orifice, Pitot tube, Venturi, and Annubar flowmeters require regular purging of impulse piping. Similarly, the transducers require periodical checking of zero and range setting.

Suggest changing to "In the case of deterioration or damage to the orifice edge, it is essential to check its sharpness, as it can lead to flowmeter reading variations of up to 20%.

They are generally self-monitored and give information regarding deviation in accuracy or failure of probe or electrode. Whenever cleaning of probes or electrodes is required, those should be cleaned as per manufacturers' recommendations.

Where deposits are to be expected in any flowmeter, the same should be regularly inspected and cleaned as per the experience gained over time, as these deposits affect the accuracy of the measurement, vortex meter, magnetic flowmeter, ultrasonic flowmeter, may show erroneous reading in the presence of deposits. In an intermittent water supply, the corrosion rate of the pipe increases due to chlorine and air. The formation of incrustation and subsequent descaling effect flowmeter working especially differential pressure type, turbine meters.

13.13.3.2 Flowmeter Calibration

There are two philosophies of flowmeter calibration. One is that it is better to have a fixed calibration system with all the associated technical back up and with the flowmeters being brought to the calibration system; the other favours calibrating in situ leaving the flowmeters in their installed condition and using a portable calibrator. The former will generally provide the more accurate calibration, but the latter has the advantage of accounting for site-specific effects, such as proximity to hydraulic disturbances. It is necessary to decide carefully which option to adopt.

There is often no choice but to carry out in situ calibration where:

- flow cannot be shut off;
- site-specific conditions have to be accounted for;
- the meter is so large that removal, transport, and testing costs would be prohibitive.

The major constraint with the in situ calibration technique is that the high accuracy laboratory calibration cannot be matched in the field and accuracies of $\pm 2\%$ to $\pm 5\%$ is all that can be achieved, and such field tests are called confidence checks rather than absolute calibrations. Such checks are often the precursor to the removal of flowmeter for laboratory calibration or replacement.

For field tests, the following methods can be used:

- i. Clamp-on devices
- ii. Thermodynamic method
- iii. Velocity-area methods (insertion meters)
- iv. Tracer methods

v. Flow simulators

Normally, the manufacturers of the flowmeters provide laboratory calibration of the flowmeters in their works. Some of the Government agencies also provide laboratory calibration, vis., Fluid Control Research Institute (FCRI), Palakkad, Central Water and Power Research Station (CWPRS), Pune and Institute for Design of Electrical Measuring Instruments (IDEMI), Mumbai.

Table 13.11 gives the performance factors of flowmeters and Table 13.12 gives installation constraints of flowmeters. Table 13.13 gives fluid property constraints for flowmeters. Table 13.14 gives economic factors of flowmeters. The installation methods for various types of flowmeters along with maintenance and service are discussed in Table 13.15.

Table 13.11: Performance Factors of Flowmeters

Sr. No.	Type of the flowmeter	Linearity %	Repeatability (%)	Rangeability	Pressure drop at maximum flow	Flow parameter measured
1.	Orifice	0.25% FS to 1% FS	±0.2% FS	3 or 4:1	3-4	R
2.	Venturi	0.25% FS to 1% FS	±0.2% FS	3 or 4:1	2	R
3.	Variable area	±1% FS to ±5% FS	±0.5% FS to ±1% FS	1% FS	10:1	3R
4.	Annubar	0.5% R to 1% R	±0.05% R to ±0.2% R	4 to 10:1	1/2	Vm
5.	Turbine	±0.15% R to ±1% R	±0.02% R to ±0.5% R	5 to 10:1	3	R
6.	Insertion Turbine	±0.25% R to ±5% R	±0.1% R to ±2% R	10 to 40:1	1-2	Vp
7.	Vortex	±1% R	±0.1% R to ±1% R	4 to 40:1	3	R
8.	Insertion Vortex	±2% R	±0.1% R	15 to 30:1	1	Vp
9.	Electro Magnetic	±0.2% R to ±1% R	±0.1% R to ±0.2% FS	10 to 100:1	1	R
10.	Insertion Elec. Mag.	±2.5% R to ±4% R	±0.1% R	10:1	1	Vp
11.	Doppler	No data	±0.2% FS	5 to 25:1	1	Vm, R
12.	Transit time	±0.2% R to ±1% R	±0.2% R to ±1% FS	10 to 300:1	1	R

Legends: R: Flowrate, Vp: Point velocity, NS: Not specified; T: Volume flow; % R: Percentage flowrate; 1: Low; Vm: Mean velocity; % FS: Percentage full scale; 5: High

Table 13.12: Installation Constraints for Flowmeters

Sr. No.	Type	Orientation	Direction	Quoted range of upstream lengths	Quoted range of minimum downstream	Pipe Diameter (mm)
1.	Orifice	H, VU, VD, I	U, B	5D/80D	2D/8D	6 to 2600
2.	Venturi	H, VU, VD, I	U	0.5D/29D	4D	>6
3.	Variable area	VU	U	0D	0D	2 to 150
4.	Annubar	H, VU, VD, I	U, B	2D/25D	2D/4D	>25
5.	Turbine	H, VU, VD, I	U, B	5D/20D	3D/10D	5 to 600

Sr. No.	Type	Orientation	Direction	Quoted range of upstream lengths	Quoted range of minimum downstream	Pipe Diameter (mm)
6.	Insertion turbine	H, VU, VD, I	U, B	10D/80D	5D/10D	>75
7.	Vortex	H, VU, VD, I	U	1D/40D	5D	12 to 400
8.	Insertion Vortex	H, VU, VD, I	U	20D	5D	>200
9.	Electromagnetic	H, VU, VD, I	U, B	0D/10D	0D/5D	2 to 3000
10.	Insertion magnetic	H, VU, VD, I	U, B	25D	5D	>100
11.	Doppler	H, VU, VD, I	U, B	10D	5D	>25
12.	Transit time	H, VU, VD, I	U, B	0D/50D	2D/5D	>4

Legends: H: Horizontal flow; U: Unidirectional flow; VU: Upward vertical flow; B: Bidirectional flow; VD: Downward vertical flow; D: Inner diameter of pipe; I: Inclined flow.

Table 13.13: Fluid Property Constraints for Flowmeters

Sr. No.	Type	Maximum pressure (bar)	Temperature Range (°C)	Minimum Reynold's number	More than one phase (Gas or liquid)
1.	Orifice	400	<650	3×10^4	P
2.	Venturi	400	<650	10^5	P
3.	Variable area	700	-80 to + 400	No data	N
4.	Annubar	400	<540	10^4	N
5.	Turbine	3500	-260 to +530	10^4	N
6.	Insertion Turbine	70 to 250	-50 to +430	10^4	N
7.	Vortex	260	-200 to +430	2×10^4	P
8.	Insertion Vortex	70	- 30 to +150	5×10^3	N
9.	Electromagnetic	300	-60 to +220	No limit	S/P
10.	Elect. Insertion	20	+5 to +25	No data	N
11.	Doppler	Pipe pressure	-20 to +80	5×10^3	S
12.	Transit time	200	-200 to +250	5×10^3	N/P

Legends: S: Suitable; P: Possible; N: Not suitable

Table 13.14: Economic Factors of Flowmeters

Type	Installation cost	Calibration cost	Operation cost	Maintenance cost	Spares cost
Orifice	2-4	1	3	2	1
Venturi	4	1-4	2	3	3
Variable area	1-3	2	2	1	1
Annubar	2	3	2	2	2
Turbine	3	4	3	4	4
Insertion Turbine	2	3	2	2	3
Vortex	3	3	3	3	3
Insertion Vortex	2	3	2	3	3
Electromagnetic	3	3	1	3	3
Insertion Ele. Mag.	2	3	2	3	2
Doppler	1-3	1	1	3	2
Transit time (time of flight)	1-3	3	1	3	2

Legends: 1: Low; 5: High

Table 13.15: Installation and Maintenance of Flowmeters

Type	Installation	Pipeline ahead of meter	Maintenance during operation	Self-Monitoring	Service
Turbine meter	Flanged electrical installation	Conditioning section	Maintenance free, monitor, possible foreign lubrication	Not possible	—
Vortex meter	Flanged water electrical connections or installation,	Conditioning section installation	Maintenance free	Error monitoring	Electronic monitor functions and test values
Differential pressure Meters	Primary in impulse piping, converter power supply	Long conditioning sections	Regular monitoring	Not possible	Direct measurement at primary
Variable area	Flanged or threaded	No restrictions	Maintenance free	Constant appearance	—

Type	Installation	Pipeline ahead of meter	Maintenance during operation	Self-Monitoring	Service
meter	connections				
Electromagnetic flowmeter	Flanged connections, electrical connections	No conditioning section	Maintenance free	Monitoring with error announcements	Electronic control functions and test simulator
Ultrasonic meter	Flanged connections or welding nipples, electrical installation.	Long conditioning section	Maintenance free	Signals for signal loss	-

13.13.4 Problems Encountered in Flowmeter Performance

There are many problems encountered during the life of the flowmeter. Some of the common performance-related issues/problems that are encountered during its operation due to some causes along with remedial action are discussed in Table 13.16.

Table 13.16: Common Problems Encountered in Flowmeter Performance

S. No.	Problems	Causes	Flowmeter	Remedial Action
1.	Erratic reading	Operated below lower range having limited rangeability of flowmeter	Differential pressure type	Replace flowmeter
		Operated below lower range having limited rangeability of flowmeter	Linear flowmeter	Change range setting
		Less static pressure	D.P. type	Remove air trap
		Clogged impulse piping	D.P. type	Clear the choke up
		Air trapped in impulse piping	D.P. type	Remove air trap
		Frequent air trap in impulse piping	D.P. type	Change impulse piping slope to minimum 1:10, If still the problem persists change the flowmeter
		Damaged impulse piping	D.P. type	Rectify impulse piping
2.	Unsteady reading: (oscillating)	β ratio of more than 0.65	D.P. type	Redesign orifice
		Pulsating flow	D.P. and Linear type	Condition the flow
3.	Inaccurate reading	Pipeline internally incrustated	D.P. and Linear type	Clean the internal surface of pipeline
		Scaling is formed at tapping points	D.P. type	Clean the tapping points
		Orifice edge gets blunt	D.P. type	Replace orifice plate
		Flowmeter downstream is opened within the range of 50 times dia pipe length	D.P. type	Extend the downstream pipeline beyond 50 times dia length
		Unsymmetrical formation of vena contract due to the large diameter of the throat in relation to static pressure	D.P. (orifice type)	Redesign the orifice
		Mismatch between flowmeter and pipeline	D.P. and Linear type	Remove the mismatch
		Absence of sufficient conditioned approach pipeline	D.P. and Linear type	Provide sufficient conditional approach pipeline
		Foreign particles such as pieces of concrete, bricks, debris. etc. are gathered at upstream of the orifice	D.P. (Orifice)	Remove them
		Flanged coupling used with flowmeter leaking	D.P. and Linear type	Rectify the leakage
		The pipeline may not be	D.P. and	Replace the pipe length

S. No.	Problems	Causes	Flowmeter	Remedial Action
		cylindrical within the range of 0.3% of the diameter of the pipe	Linear type	of 2 times dia immediate upstream of the flowmeter
		Pipeline partially filled	D.P. and Linear type	Install valve downstream of the flowmeter for throttling

13.13.4.1 Calibration of Pressure Measuring Instruments

Pressure instrument calibration is the process of adjusting the instruments output signal to match a known range of pressure. All instruments tend to drift from their last setting. This is because springs stretch, electronic components undergo slight changes on the atomic level, and other working parts sag, bend, or lose their elasticity.

The calibration procedure includes zero, span, and linearity adjustments. The pressure is varied with the help of a pneumatic calibrator so as to give desired pressures to the instrument. The settings are carried out on the instrument for zero and span adjustment on the basis of applied pressures. For carrying out linearity, setting various pressures between zero and maximum range of the instruments are applied and adjusted the output of the measuring instrument with the help of controls provided in the instrument.

In the case of pressure gauges, the calibration is carried out by means of dead weight tester. In the absence of a pneumatic calibrator, the air can be supplied to the instrument with proper pressure regulator, and pressure is measured with the help of a manometer so as to calibrate the instrument. The calibration should be checked every 3, 6, or 12 months depending upon the use and accuracy expected, as per the manufacturer’s recommendation and latest ISO standards. Maintenance of pressure instruments is essential for their proper working and accurate reading. It also improves the life and reliability of the instruments.

13.13.4.2 Preventive Maintenance

The manufacturer of the instrument gives the instructions in the manual supplied along with the instruments. These instructions explain how to maintain the instrument. Generally, these consist of the following categories:

1. Visual Inspection:

Any damage to piping or wiring of the instrument observed should be immediately rectified. It avoids the entry of foreign bodies into the system and further damage to the instrument.

2. Venting or Blow down

Liquid lines are generally clogged subsequently if those are not vented periodically. Similarly, air or gas in the liquid columns gives wrong readings. In order to avoid such incidents, it is essential to blow down the instrument piping periodically on the basis of experience gained in the field.

3. Cleaning and Lubrication

Instruments with mechanical linkages undergo wear and misalignment. Dirt may clog the linkages, causing the mechanism to become less flexible. If not attended these kinds of faults, the instrument may breakdown subsequently. Clogging can be removed by cleaning, and the working of the instrument can be improved by lubrication as per manufacturer's recommendations. Dust can be removed from the panels as well as from the instruments with the help of an air blower. If auto test facility is provided on the instrument by the manufacturer, the same can be used to check the performance of the instrument daily. If any kind of fault occurs, in such instrument, the same is identified and displayed by the instrument itself. A typical troubleshooting

chart for pressure and level measuring instrument (electronic transmitter type) is given in Table 13.17 and typical specification for online measurement of pressure are given in Table 13.18.

Table 13.17: A Typical Troubleshooting Chart for Pressure and Level Measuring Instrument (Electronic Transmitter Type)

Fault	Possible Causes	Corrective Action
Low output or zero output or High output or Erratic output	Power Supply	Check the output of power supply
		Check for short and multiple grounds
		Check polarity of connections
		Check loop impedance
	Pressure tapping	Check the pressure connection
		Check for leakage or blockage
		Check for entrapped air or gas in the line
	Transmitter	Check for shorts in sensor leads
		Check connector to transmitter
		Check for amplifier assembly by replacing it with the spare one
Sensing element	Check the sensing element for its working by gently tapping it	
Tapping by hand gently the mechanism sensor does not respond	Mechanical	Check mechanical linkage
		Check for dirt finding
		Excessive wear, misalignment
		For dirt clean and lubricate as per manufactures recommendations
		Realign mechanical parts if necessary
		For wear replace the worn-out components
	Electrical	Replace electrical/electronic subassemblies and perform calibration

Table 13.18: Typical Specification for Online Measurement of Pressure

Parameters	Descriptions
Specifications	Pressure Range 0 to 10/20/50/100 Kg/cm ² g
Process Temperature Range	-20 to + 125 °C
Output Signal	4 to 20 mA with superimposed digital communication protocol HART, 2-wire
Signal Range	4 to 20 mA HART
Signal on Alarm	As per NAMUR NE 43 • 4 to 20 mA HART Options: Max. alarm: can be set from 21 to 23 mA (factory setting: 22 mA) a) Hold measured value: last measured value is held b) Min. alarm: 3.6 mA
Resolution	Current output: 1 microAmp Display: can be set (setting at the factory: presentation of the maximum accuracy of the transmitter)
Response Time	<250 ms
Damping	Via local display, handheld terminal or PC with the operating programme, continuous from 0 to 999 s

Parameters	Descriptions
	Additionally, for HART: via DIP switch on the electronic insert, switch position "on" = value set in the 2 Sec As default
Supply Voltage	11.5 to 45 V DC
Residual Ripple	No influence on 4 to 20 mA signal up to $\pm 5\%$ residual ripple within the permitted voltage range [according to HART hardware specification HCF_SPEC-54 (DIN IEC 60381-1)]
Influence of Power Supply	$< 0.0006\%$ of URL/1 V
Reference Accuracy	$\pm 0.075\%$ of the set Span
Climate Class	Class 4K4H (air temperature: -20 to 55 °C/ -4 to $+131$ °F, relative humidity: 4 to 100%) satisfied as per DIN EN 60721-3-4 – Seal Capsuled electronics.
Housing	Die Cast Alu. Housing
Diaphragm Material	Ceramic Dry measuring cell, Capacitive measuring cell
Display Operation	3 Key Push button for configuration without HART COMMUNICATOR. A 4-line liquid crystal display (LCD) is used for display and operation
Long-Term Stability	$\pm 0.25\%$ URL/year for 1 year, 5 year
Turn Down	100:1

13.13.4.3 Radar Level Transmitters

They provide a non-contact type of level measurement in case of liquids in a metal tank. They make use of EM, i.e., electromagnetic waves usually in the microwave X-band range which is approximately 10 GHz. Hence, they can be also known as microwave level measurement devices. However, there are some differences between radar and microwave types. They are:

- i. Power levels in the case of radar systems are about 0.01 mW/cm^2 , whereas in the case of microwave systems, these levels range from 0.1 to 5 mW/cm^2 .
- ii. Microwaves can work at higher energy levels; hence, they are competent enough to endure extra coating as compared to radar level detectors.

A radar level detector includes:

- i. A transmitter with an inbuilt solid-state oscillator
- ii. A radar antenna
- iii. A receiver along with a signal processor and an operator interface

The operation of all radar level detectors involves sending microwave beams emitted by a sensor to the surface of the liquid in a tank. The electromagnetic waves, after hitting the fluid's surface, return back to the sensor which is mounted at the top of the tank or vessel. The time taken by the signal to return, i.e., Time of Flight (TOF) is then determined to measure the level of fluid in the tank. The specifications of a Radar Level Transmitter are given Table 13.19.

Table 13.19: Radar Level Transmitter

Radar – Microwave type level transmitter	Service: Raw Water (Non-Contact Type)
Transmitter	
Type	Microwave level measurement
Principle	Pulse Time of Flight

Radar – Microwave type level transmitter	Service: Raw Water (Non-Contact Type)
Output	4–20 mA HART Current
Housing	Die Cast Aluminium
Electromagnetic compatibility	Interference Immunity to EN 61326, Annex A (Industrial) and NAMUR
Ingress protection	IP65/IP 66/IP 67
Accuracy	±3 mm
Area classification	Non-Hazardous
Display	4-line LCD Display. Menu guided operation. Display of Envelope Curve.
Configuration	Using the keypad on display
Sensor	
Range	Liquids 0 to 5 m and 0 to 10 m depending on Tank size
Temperature range	-40 °C ... +80 °C
Max pressure	3 bar abs
Materials	Sensor: PVDF Seal: EPDM
Antenna seal	FKM Viton
Process connection	Threaded or universal flange dependent on model selection
Degree of protection	IP65

13.13.5 Telemetry and SCADA Systems

13.13.5.1 Manual Monitoring

Normally, the managers of O&M of water utilities monitored levels in service reservoirs, pressures, and flows in a distribution system and on the operation of pumps such as hours of pumping and failure of pumps and monitored water quality by measuring residual chlorine. The manager usually uses the telephone line or wireless like VSAT or GPRS/GSM unit to gather the data, uses his discretion gained with experience, and took decisions to ensure that the system is operating with the required efficiency. Manual collection of data and analysis is an outdated practice and may not be helpful in large undertakings if water utilities have to aim to offer enhanced customer service by improving water quality and service level with reduced costs. This is possible if the management acquires operational data at a very high cost.

13.13.5.2 Telemetry

The inspection, monitoring, and control of O&M of a water utility can be automated partially through telemetry. Telemetry enables regular monitoring of the above data on a real-time basis and the data is provided to anyone in the organisation who can review the data and make a decision. In a telemetry system, probes/sensors will be used which will sense and generate signals for the level, pressure, flow, and water quality like pH, turbidity, residual chlorines in a given unit, and transmit the signals by radio/by telephone, VSAT, GSM/GPRS. Normally, a radio link is used and a telephone line with modem is used as spare communication. Microwave satellite or fibre-optic transmission systems are also used for data transmission. Water pumping stations may communicate via a cable buried with the pipe. However, there may be locations where the main power may not be available and, hence, solar panels with a battery charger are used to power the remote terminal unit (RTU) and the radio, VSAT, GSM/GPRS. In urban areas, RTUs can communicate on cell phones and or packed radio networks. For remote locations satellite technology is also available.

i. Data for Collection by Telemetry

The data includes levels in service reservoirs, pressures and flows in a distribution system, flows/quantity and water quality like pH, turbidity, residual chlorines of delivery into a service reservoir and data on the operation of pumps such as voltage, amperes, energy consumed, operating times and downtimes of pumps and chlorine residuals. In a telemetry system, up-to-the-minute real-time information is gathered from a remote terminal unit located at the water treatment plant, reservoir, flowmeter, pumping station, etc., and transmitted to a central control station where the information is updated, displayed and stored manually or automatically.

ii. Processing Data from Telemetry

The meter readings from reservoirs provide useful information for managing the distribution system and help in preventing overflow from reservoirs. However, the effectiveness of telemetry in pumping operations is dependent on the reliability of instrumentation for measuring flows, pressures, KWh meters, etc. Standard practice is to calculate pump efficiency and water audit calculations on a monthly basis. Telemetry can also be used to supervise a water hammer protection system wherein the pump failures are linked to initiate measures to prevent the occurrence of water hammer.

13.14 SCADA Systems

Instead of manual review of data collected by telemetry and initiating action manually, if telemetry is extended to include actions based on the data for remote control of pumps and other equipment, then such a system is known as supervisory control and data acquisition (SCADA). SCADA is a computer-aided system that collects, stores, and analyses the data on all aspects of O&M. It gives a better understanding of what is happening in terms of water quantity or water quality which is sourced and supplied. SCADA can do any activity like on/off any equipment or start /stop.

The operating personnel can retrieve the data and control their operations and sometimes the system itself is programmed to control the operations on the basis of the acquired data. SCADA enhances the efficiency of the O&M personnel who are better informed about the system and hence are in full control of the operations. Whether in a telemetry system or a SCADA system, up-to-the-minute real-time information is gathered from the remote terminal unit located at the water treatment plant, reservoir, flowmeter, pumping station, etc., and transmitted to a central control station where the information is updated, displayed, and stored manually or automatically. In a SCADA system, the information is linked to a supervisory system for local display, alarm annunciation, etc., which may be linked to remote control of pumping operations or operation of valves, etc.

13.14.1 Data Collected in SCADA/Smart Metering System

SCADA systems will have probes/sensors which will sense and generate signals for the level, pressure, and flow in a given unit, and transmit the signals for storage and analysis on the computer. The signals are transmitted by radio, by telephone, microwave satellite, or fibre-optic transmission systems. SCADA systems can include the network diagrams of the distribution system of which detailed sketches of a particular area can be viewed by the operator if necessary to observe the current operating data such as flow, pressure, level, or residual chlorine.

SCADA systems in water distribution are programmed for the collection and processing of the following information.

- i. To monitor levels in service reservoirs, pressures and flows in a distribution system;
- ii. To monitor and store data on levels in SRs, or flows/quantity of delivered into SR or pressures of the distribution system and generate alarms for threshold values of levels, flows and pressures to initiate operation of valves and pumps;
- iii. To monitor and store data on the operation of pumps such as voltage, amperes, energy

- consumed, operating times and down times of pumps;
- iv. To measure and record chlorine residuals and generate alarms at threshold values of residual chlorine in the distribution systems.

13.14.2 Analysis of Data from SCADA/Smart Metering

SCADA systems can be designed to analyse the data and provide daily, weekly, monthly, and/or annual reports or schedules. It also helps in monitoring the inventories on spare parts and plan requirement of spares. Responses for different scenarios such as seasonal changes or any emergencies can be programmed into SCADA. The information stored in the SCADA can be easily retrieved and analysed. Typical information that could be generated in the system includes consumption patterns linked to the weather conditions, plots on pressures against flows, electrical energy consumption linked to consumer demands, record on system leaks, record on pump failures, areas with fewer chlorine residuals, etc. A typical SCADA system architecture and dashboard in shown in figure 13.21 & 13.22.

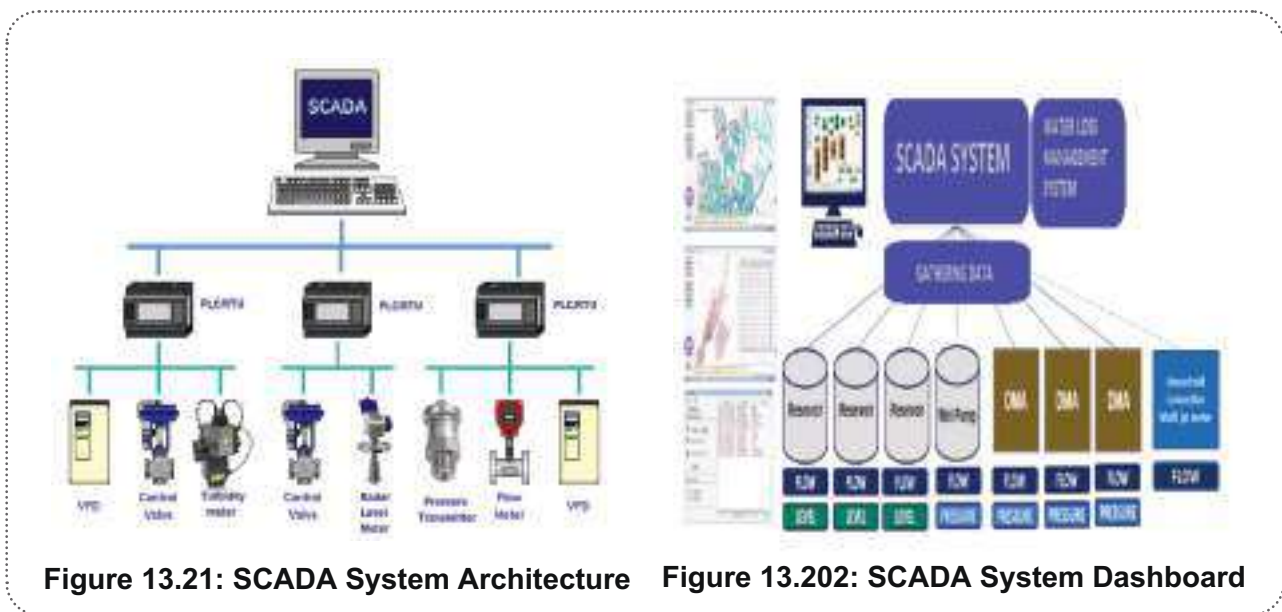


Figure 13.21: SCADA System Architecture Figure 13.202: SCADA System Dashboard

13.14.3 Limitations of SCADA/Smart Metering/Communication

Before installing a SCADA, the utility staff should visit facilities with SCADA and discuss with the utility managers, then decide the scope of SCADA to be provided in their utility. The objective of SCADA should be to make the job of the operator easier, more efficient, and safer to make their facilities performance more reliable and cost-effective. There is no doubt that SCADA enables better capacity utilisation and helps in improved service levels at low operating cost. SCADA designing calls for careful planning and requires a phased implementation, particularly dependent on appropriate training of utility staff and their willingness to adopt the new technology.

The availability of power supply is very essential to the efficient functioning of the system. Wherever possible, the RTU for the flowmeter or pressure sensor and water quality like pH, turbidity, residual chlorine is provided power from electricity mains via a battery that acts as a buffer in case of mains failure. There may be metering locations for flow and pressure sensors without any source of power close by. In such cases, solar power may be one alternative. Initially installations at such locations may operate well but they are always subject to poor after-sales service by vendors, vandalism, and theft.

Ultimate improvement in the water supply distribution system cannot be achieved through the advanced application of technology like SCADA. The utility staff should have reached a reasonable level of managerial capabilities even with conventional methods of monitoring and control by adopting

a holistic approach when the SCADA may further enhance their capabilities; SCADA by itself is not the answer for poor or inefficient management.

13.15 Conclusion

The present field measurement market, which caters to the water quantity and quality, is open and there are many new technologies available based on the requirement of the purchaser. If the right instrumentation for measurement and control like a water meter, flowmeter, etc., are selected and installed properly, maintenance cost, manpower cost, etc., will be reduced drastically and accuracy also will be maintained.

It is also pertinent to mention that there is no clear data available in the country regarding the quantity of water drawn or abstracted from the source or treated in a treatment plant or consumed by consumers. As the precious water resources are getting scarce and depleted day by day, it is essential to adopt technologies for ensuring proper measurement, maintaining quality, and conservation. By adapting the necessary field instrumentation devices, water balance, NRW, etc., may be known and necessary steps may be taken for better management of water. The correct and accurate measurement of inputs and outputs need to be given due weightage and importance in all water utilities for effective and productive utilisation of precious potable water resources by way of water and energy audits.

There is a need for judicious use and conservation of limited availability of water, and it is important that a demand management programme is introduced in each ULB by expanding the consumer water metering programme. It is essential for every ULB/Water Board to have a metering policy similar to the example set by Chennai Metro Water and Sewerage Board. This water meter policy provides the objective, roles and responsibilities of all stakeholders and the technical standards for the water metering programme. The consumers are classified as domestic, partly commercial, commercial, industrial, institutional, and municipal bulk supply, based on the nature of water usage activity by the consumer. The policy should cover types of consumers for metering, selection of meter, its specification and installation guidelines, and in addition, should cover the tariff, billing and collection, and grievance redressal procedures related to metering. Further, the responsibilities of the ULB/Water Board and consumers regarding metering can be described. Consumer meters shall be owned by the Board and fixed rental charges to be levied on the consumers along with the water charges. The rental charges shall be used for the specific purpose of routine and periodical maintenance of the meters and regular meter replacement programme by the ULB/Water Board. The day-to-day safety and upkeep of the meters shall be the responsibility of the consumer. If any wilful tampering or damage of the meters occurs other than natural wear and tear, the ULB/Water Board will undertake replacement of such defective meter and the cost of such exceptional repair or replacement of meter shall be recovered from the consumer with advance notice. Having a metering policy will also enable the ULB/Water Board to have back-to-back long-term warranty with various meter manufacturers.

To make the ULB/Water Board sustainable, a tariff for water supply has to be fixed for each category of consumers for metered and unmetered premises. Preferably, the tariff has to be designed in such a way that a long-term tariff for water supply is fixed for different categories of consumers based on a volumetric tariff with lowest the tariff for domestic, full cost recovery for commercial, and industries, and should include institutional, municipal bulk supply, and mobile water supply.

In summary, the key objectives of the tariff and metering policy would be to

- a) promote water conservation by encouraging efficient water use;
- b) reduce non-revenue water (NRW) and increase cost recovery;
- c) ensure fairness and equity to all Consumers in charging for water services;

- d) achieve 100% of metering to all households including all high rise and commercial connections;
- e) set out roles and responsibilities of both ULB/Water Board and consumer in relation to the installation of metered connections, maintenance of the water meters.

One of the key advantages of implementing a metering system to improve efficiencies of a ULB/Water Board is that it lends itself for a Public-Private Partnership (PPP) under the Hybrid Annuity Model (HAM) suggested under AMRUT 2.0 guidelines where viability gap funding is available. The HAM can be structured into a performance-based contract with partial funding by a private concessionaire, wherein a long-term performance-based O&M can be structured comprising fixed and variable payments linked to performance such as efficiency of redressal of customer complaints, meter reading, billing and distribution efficiency, response time to new water supply connections, and functioning of water meters.

General specifications to be followed for water meters to sustain 24×7 water supply system:

- In case of static meters, the water meters should be Ultrasonic or Electromagnetic with shelf life of atleast 10 years, the battery life of these should not be less than 10 years.
- In case of mechanical multijet meters or mechanical multijet AMR, the minimum shelf life shall be of 5 years and the battery life should not be less than 5 years.
- The suppliers shall be made responsible for O&M for 10 years in respect of static meters and 5 years in respect of mechanical meters including for repair and replacement of meters.
- Water meters should have FCRI and OIML/MID certification and approval for legal metrology. Such certificate should be issued in the name of the manufacturer supplying the meters.
- Water meter should be approved/certified by FCRI for ISO 4064-1 and ISO 4064-3 of 2014.
- Water meter should be IP68. In case of electro-magnetic and Ultrasonic meters it should be R 400 and above. In case of mechanical meters with smart communication AMR/AMI it can be R160 due to limitations.
- Smart meters/ static meters should enable NB-IoT/LoRaWAN/Walkthrough/Drive through for data reading.
- Water meter should provide one reading per day and should have internal memory to store meter reading for 90 days.
- Performance tests related to influence factors and disturbances is mandatory for electromagnetic / ultrasonic static meters and all type of meter manufacturers need to provide conformity assessment with respect to quality assurance of the production process with technical documentation and also type design approval with endurance certificate as conducted by FCRI for module approval program (MAP) is mandatory for long life product.

If the ULB is proposing for smart water meters in water supply systems, the following standards (Table 13.20) shall be followed:

Table 13.20 Applicable Standards for Water Meters and Flowmeters

S.No.	Standard/Reference	Title/Description
General		
1	BS: 7405:1991 confirmed year: 2017	Selection and application of flowmeters for the measurement of fluid flow in closed conduits
2	BS: 5792:1980 Replaced by: BS EN ISO 20456:2019	Specification for Electro Magnetic flowmeters
3	BS EN ISO: 6817:1997 Replaced by: BS EN ISO	Measurement of conductive liquid flow in closed conduits – Method using Electromagnetic flowmeters

S.No.	Standard/Reference	Title/Description
	20456:2019	
4	ISO Recommendation: R-541: 1967(E) Replaced by: ISO 5167-1:2003	Measurement of fluid flow by means of orifice plates and nozzles
5	ISO 9104:1991/ Revised by: ISO 20456:2017 BS 7526: 1991	Measurement of fluid flow in closed conduits — Method of evaluating the performance of electromagnetic flowmeters for liquids
6	BS: 6199: 1991/ ISO 9368:1990 Confirmed Year:1998	Measurement of liquid flow in closed conduits by using weighing and volumetric methods
7	IS: 4477 Part-2: 1975 Reaffirmed Year: 2016	Methods of measurement of fluid flow by means of Venturi meters: Part-2 Compressible Liquids
8	IS 2951 Part I: 1965 Reaffirmed Year: 2017	Recommendations for estimation of flow of liquids in closed conduits Part I: Head loss in straight pipes due to frictional resistance
9	IS 14615 Part I: 1999: 2018	Measurement of fluid flow by means of pressure differential devices — Part I: Orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full
10	IS 9115: 1979 Reaffirmed Year: 2017	Method for estimation of incompressible fluid flow in closed conduits by Bend meters
11	IS 779: 1994 Reaffirmed Year: 2015	Water meters (Domestic type) – Specification (Sixth revision)
12	IS 2373: 1981 Reaffirmed Year: 2017	Specifications for water meters (Bulk type) (Third revision)
13	IS 6784: 1996 Reaffirmed Year: 2017	Methods for Performance Testing of Water Meters
14	BS 5728	Measurement of flow of cold potable water in closed conduits Part I (1979): Specification for single meters Part II (1980): Specification for installation requirements for single meters Part III (1997): Methods for determining principal characteristics of single meters
15	ISO: 4064:2014 Confirmed Year: 2019	Water meters for cold potable water and hot water Part-1: Metrological and technical requirements Part-2: Test methods and equipment Part-5: Installation requirements
16	AWWA Manual 6	Water Meters – Selection, Installation, Testing and Maintenance
17	IS 17482:2020	Drinking Water Supply Management System — Requirements for Piped Drinking Water Supply Service

S.No.	Standard/Reference	Title/Description
Closed Pipe Flow Measurements		
1	ISO 1088: 2007 Confirmed Year: 2020	Velocity-area methods using current-meters — Collection and processing of data for determination of uncertainties in flow measurement
2	ISO 3354: 2008 Confirmed Year: 2017	Velocity-area method using current-meters in full conduits and under regular flow conditions
3	ISO 4006: 1991 Confirmed Year: 2019	Measurement of fluid flow in closed conduits — Vocabulary and symbols
4	ISO 4064-1: 2005 Replaced by: ISO 4064-1:2014	Measurement of water flow in fully charged closed conduits — Meters for cold potable water and hot water — Part 1: Specifications
5	ISO 4064-2: 2014 Confirmed Year: 2019	Water meters for cold potable water and hot water — Part 2: Test methods
6	ISO 4064-5: 2014 Confirmed Year: 2019	Water meters for cold potable water and hot water — Part 5: Installation requirements
7	ISO 4185: 1980 Confirmed Year: 2019	Measurement of liquid flow in closed conduits — Weighing method
8	ISO 5167-1: 2003 Confirmed Year: 2014 Status: Current	Flow Measurement via Differential Pressure Methods: General
9	ISO 5167-2: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Orifices
10	ISO 5167-3: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Nozzles
11	ISO 5167-4: 2003 Confirmed Year: 2014	Flow Measurement via Differential Pressure Methods: Venturis
12	ISO 5168: 2005 Reaffirmed 2015	Measurement of fluid flow — Procedures for the evaluation of uncertainties
13	ISO 6416: 2004 Revised by ISO 6416:2017	Measurement of discharge by ultrasonic (acoustic) method
14	ISO/TR 9464: 2008 Confirmed Year: 2019	Guidelines for the use of ISO 5167
15	ISO 6817: 1992 Replaced by: ISO 20456:2017	Closed Pipe Flow Measurements: Electromagnetic Flowmeters
16	ISO 8316: 1987 Confirmed Year: 2019	Flow Measurement by Volumetric Tank Collection Method
17	ISO 9104: 1991 Replaced by: ISO 20456:2017	Methods of evaluating the performance of electromagnetic flowmeters for liquids
18	ISO/TR 9824: 2007	Measurement of Free Surface Flow in Closed Conduits
19	ISO 11631: 1998 Confirmed Year: 2014	Methods for Specifying Flowmeter Performance
20	ISO/NP 12242: 2012	Measurement of fluid flow in closed conduits — Ultrasonic transit time meters for liquid
21	ISO 13359: 1998 Replaced by:	Flanged Electromagnetic Flowmeters: Overall length

S.No.	Standard/Reference	Title/Description
	ISO 20456:2017	
22	ISO/TS 25377: 2007 Confirmed Year: 2013	Hydrometric Uncertainty Guidance (HUG)